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1. Scope

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- **Letters to the editor:** Communication to the editor is welcomed and will be published if they offer pertinent and/ or constructive comment on articles published in the Acta Orthopaedica Et Traumatologica Hellenica. Letters are published at the discretion of the Editorial team and should be received within three months after on-line publication of an article. Following acceptance, letters will be sent to authors for response. Letter communications should include text of no more than 500 words, up to 2 figures and 10 references, without any abstract or keywords and a maximum of 3 authors.

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10. Figures and Tables

All figures and tables need to be cited in text consecutively in the order in which they appear in text into brackets and in Arabic numbers: i.e. (Fig. 1) and (Table 1). Figure parts need to be identified with lower case letters, i.e (Fig. 1a).

Figures need to be of high quality. Vector graphics, scanned line drawings and line drawings need to be in bitmap format and should have a minimum resolution of 1,200 dpi. Halftones (photographs, drawings or paintings) need to be in TIFF or JPEG format, up to 174 mm wide and up to 234 mm high and in minimum resolution of 300 dpi.

Patient anonymity should be ensured. All identifying data (name, identification numbers, initials) must be removed from text, images and tables. If it is mandatory for a patient's face to be included in the manuscript, the eyes should be sufficiently masked. If there is a possibility that a patient may be identified from a photograph or relevant legend and text, the patient's written consent should be submitted.

A figure caption and a table caption need to be added in the figure and table section respectively for each figure and table.

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or

Papaioannou NA, Triantafyllopoulos IK, Khaldi L, et al. Effect of calcitonin in early and late stages of experimentally induced osteoarthritis. A histomorphometric study. *Osteoarthritis Cartilage* 2007; 15(4): 386-95.

- Book chapters:

Triantafyllopoulos IK, Papaioannou NA. The Effect of Pharmacological Agents on the Bone-Implant Interface. In: Karachalios Th. (ed). Bone-Implant Interface in Orthopaedic Surgery. Springer – Verlag, London 2014, pp 221-237.

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12. Review of manuscripts

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CONTENTS

LETTER FROM THE EDITOR

Adult Hip Reconstruction in Greece

It is more than 50 years that adult reconstruction emerged in Greece. Since then, it has grown as the core subspecialty in Greek Orthopaedics. With the pioneering work of Prof Hartofilakidis in cemented Charnley hip arthroplasty and congenital hip disease, as well as the work of very active contemporary hip surgeons, Greek adult reconstruction is recognized internationally. PubMed as of February 2022, using the terms hip and Greece, gives 1253 results (papers).

I had the privilege and honor to be invited as a guest editor to compile an issue for adult hip reconstruction in Greece. In this extra issue of Acta Orthopaedica et Traumatologica Hellenica, the always active Professor G. Hartofilakidis presents 11 patients that their total hip arthroplasties survived for more that 40 years follow-up. Assoc. Professor J Vlamis is presenting his view on Developmental Dysplasia of the Hip. Professor K. Malizos et al., with his continued interest in hip osteonecrosis, present the current trends and controversies of femoral head Osteonecrosis. Professor Megas and his co-authors, who has a special interest on short stems, present a systematic review about the short femoral stems with metaphyseal or meta-diaphyseal fitting in total hip arthroplasty. Rapid recovery is discussed worldwide today and thus we (Babis et al.) show our current methodology and results when applying this new way of recovery in Greek hospitals. Finally, Theo Karachalios et al. present the experience of the Department of Orthopaedic Surgery of the University of Thessaly with the technique of extended trochanteric osteotomy in revision total hip arthroplasty.

It is a fact that not all hip surgeons are represented in this issue. Many others are active in our beloved adult hip reconstruction. This issue may be a booster for all these authors to publish their experience and innovations in Acta Orthopaedica et Traumatologica Hellenica.

George C. Babis, MD

Professor and Chairman NKUA

Guest Editor

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The operation of the century almost half-century later. Report of eleven total hip replacements survived 40 years and more

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ABSTRACT

Background Total hip replacement (THR) is one of the most successful orthopaedic procedures. However, the main concern of the longevity of the prosthesis during lifelong still exists. The purpose of the present study was to report, as far as we know, for the first time in the literature the longest-term results of THR.
Methods From 164 consecutive THRs that were performed by one surgeon (GH) between 1974 and 1980 with the first-generation technique and implants introduced by John Charnley, 11 in nine patients survived 40 years and more. The surgeon who performed the operations followed these patients consistently since then.
Results At the final follow-up of the 11 hips that survived without revision for 40 years and more (mean, 42; range, 40-46), the mean patients' age was 85 years (range, 67-98). Clinically, all patients had significantly improved Merle d'Aubigné and Postel score, as modified by Charnley, in comparison with the respective pre-operative ones ($p < 0.001$).
Conclusion To our knowledge this is the first report in the literature presenting survival of a method of THR for almost half of a century. The presentation of 11 THRs survived without revision for 40 to 46 years in combination with the previously mentioned in the literature successful outcomes of the first modern THR, the Charnley's low friction arthoplasty, overpassing 30 years indicates that THR can be last lifelong for a middle-aged patient.

KEYWORDS: long-term survival, survival of total hip arthroplasty, survival of total hip replacement, low friction arthroplasty, survival over 40 years

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Introduction

Total hip replacement (THR) is one of the most successful orthopaedic procedures. It relieves patients from pain, and improves walking ability and the overall quality of life. Even patients who underwent one or more revisions had enjoyed pain relief and function improvement for a reasonable period of time [1]. However, the main concerns of the longevity of the prosthesis and the necessity of one or more reoperations during lifelong still exist.

Almost 60 years ago, the pioneer of modern THR, John Charnley [2], when he introduced his new method stated: "Neither surgeons nor engineers will ever make an artificial hip joint which will last 30 years". He died in 1982 unaware that his revolutionary method of low friction arthroplasty (LFA) will survive almost half a century and become the gold standard for comparison with the newer methods of THR.

Newer methods and implants of THR promise even better results, although there is not yet a universal agreement as to which is the best for our patients and have the longest survival prospects. This is of particular interest as there is constantly increasing elderly population, obesity, and other risk factors for OA, which are common causes leading to THR [3, 4]. The demands for THR will increase more than 4% every year between 2017 and 2024, and the cost of a primary THR will grow from US$ 6.8 billions in 2017 to US$ 9.1 billions in 2024 [5].

The purpose of the present study was to present a series of THRs survived 40 years and more and to report, as far as we know, for the first time in the literature the longest-term results of THR, an operation that seems to have been correctly characterized the operation of the century by Learmonth et al [6].

Methods

Between 1974 and 1980, 164 consecutive LFAs were performed by the senior author (Professor GH) at the Orthopaedic Department of National and Kapodistrian University of Athens, KAT Hospital. Eleven THRs in nine patients were survived 40 to 46 years (Fig. 1 and 2).

Standard Charnley technique and implants (Thackray; now DePuy, Leeds, United Kingdom), by osteotomising the greater trochanter were used in all cases [7]. The scalloped edge (non-flanged) was used in 10 hips, and the offset bore socket with a 35 mm outer diameter in one. In one hip the cotyloplasty technique was used [8, 9]. A monoblock polished femoral component with a 22.225 mm head was used in all cases. Flat-back-design stems with sharp-corners were used in 8 hips and round-back in 3 hips. The first generation cementing technique was used in all cases [10]. Prophylactic antibiotics were not given in 7 THRs performed since December 1977.

Patients were entered in our registry and reviewed clinically and radiologically at three months and one year postoperatively and at one- to three-year intervals thereafter during their lifetime. Clinical evaluation included the Merle d'Aubigné and Postel score, as modified by Charnley [11].

Statistical analysis. The analyses were performed using SPSS 24 statistical software (IBM Corp., Armonk, New York). Improvements in clinical outcome were assessed using Wilcoxon's signed-rank test. A p-value < 0.05 was considered statistically significant.

Results

The mean patients' age at the index operation was 43 years (range, 25 to 55; standard deviation (SD) 11.21). Patients were one male and 8 females. There were five left and six right hips. The primary diagnosis of these hips was congenital hip disease (CHD) in seven (five low dislocation and two high dislocation) according to Hartofilakidis classification system [8], eccentric OA in three hips, and inflammatory arthritis due to ankylosing spondylitis in one hip. Two patients had both of their hips survived for 40 years and more, while other six patients had THR of the contralateral hip survived for a mean of 27 years (range, 19 to 32; SD 5.19). Only one of the latter cases needed to be revised because of stem breakage.

At the final follow-up of the 11 hips that survived 40 years and more (mean, 42; range, 40 to 46; SD

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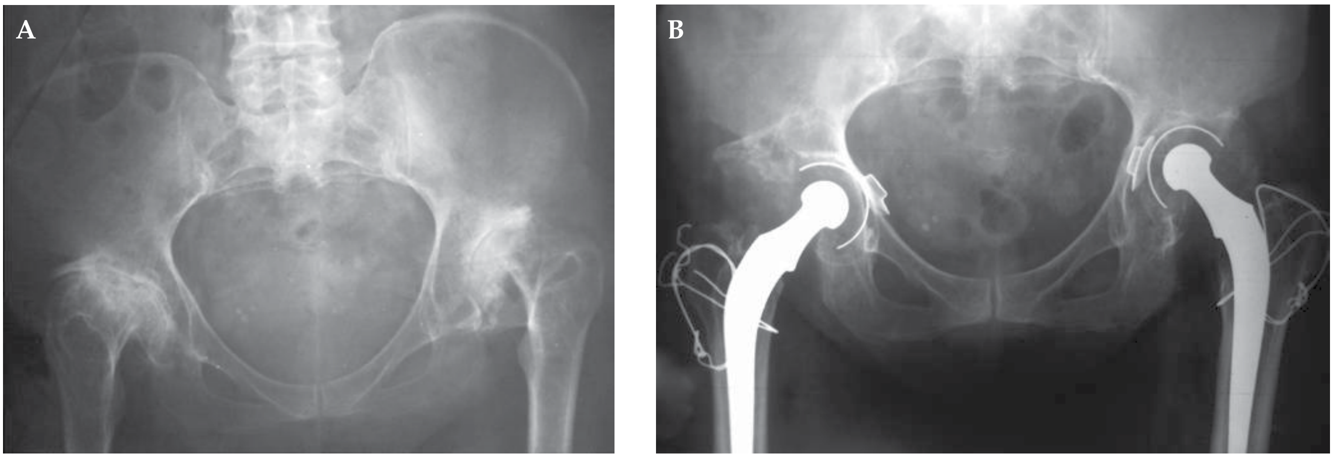

Fig. 1 *(a) Preoperative radiograph of both hips of a female patient at the age of 52 years. The patient had bilateral advanced secondary OA due to CHD of the low dislocation type. She was limping heavily, had severe pain in both hips and limited activity level. (b) Postoperative radiograph. LFA of the left and right hip was performed in 1974 and 1975, respectively. Soon after the second operation, she was pain-free from both hips, the range of motion increased significantly bilaterally, and her activity level also increased dramatically. (c) The latest follow-up radiograph 46 and 45 years postoperatively on the left and the right hip, respectively, when the patient was 98 years old. The cement mantle is not visible because radiopaque barium was not in use at that time.*

2.18), the mean patients' age was 86 years (range, 67 to 99; SD 12.45). At the preparation of the study, all of the patients were living, except one who died at the age of 95 years for a reason unrelated to the problem of the hips. Clinically, despite function (walking ability) had declined with age, all patients had significantly improved Merle d'Aubigné and Postel score, as modified by Charnley, in comparison with the respective pre-operative ones ($p < 0.001$).

Discussion

John Charnley introduced his revolutionary method of LFA that dominated the field of THR for many decades, and became the foundation stone for the contemporary prostheses during the following years. John Charnley introduced not only a successful combination of hard on soft bearing surfaces (metal on ultra-high molecular weight polyethylene), and the use of cement for fixation of the implants, but also established principles still remain of interest for orthopaedic surgeons. He is considered as the father of THR, and his method as the gold standard and a benchmark for comparison with other implants and techniques of THR that have been developed later [12].

The main principles of LFA included the use of transtrochanteric approach, the fixation of the implants with polymethacrylate (PMMA) also called acrylic or bone cement, and the use of small diameter 22.225 mm femoral head. The osteotomy of the greater trochanter and its relocation more distally at the lateral surface of the femur improves

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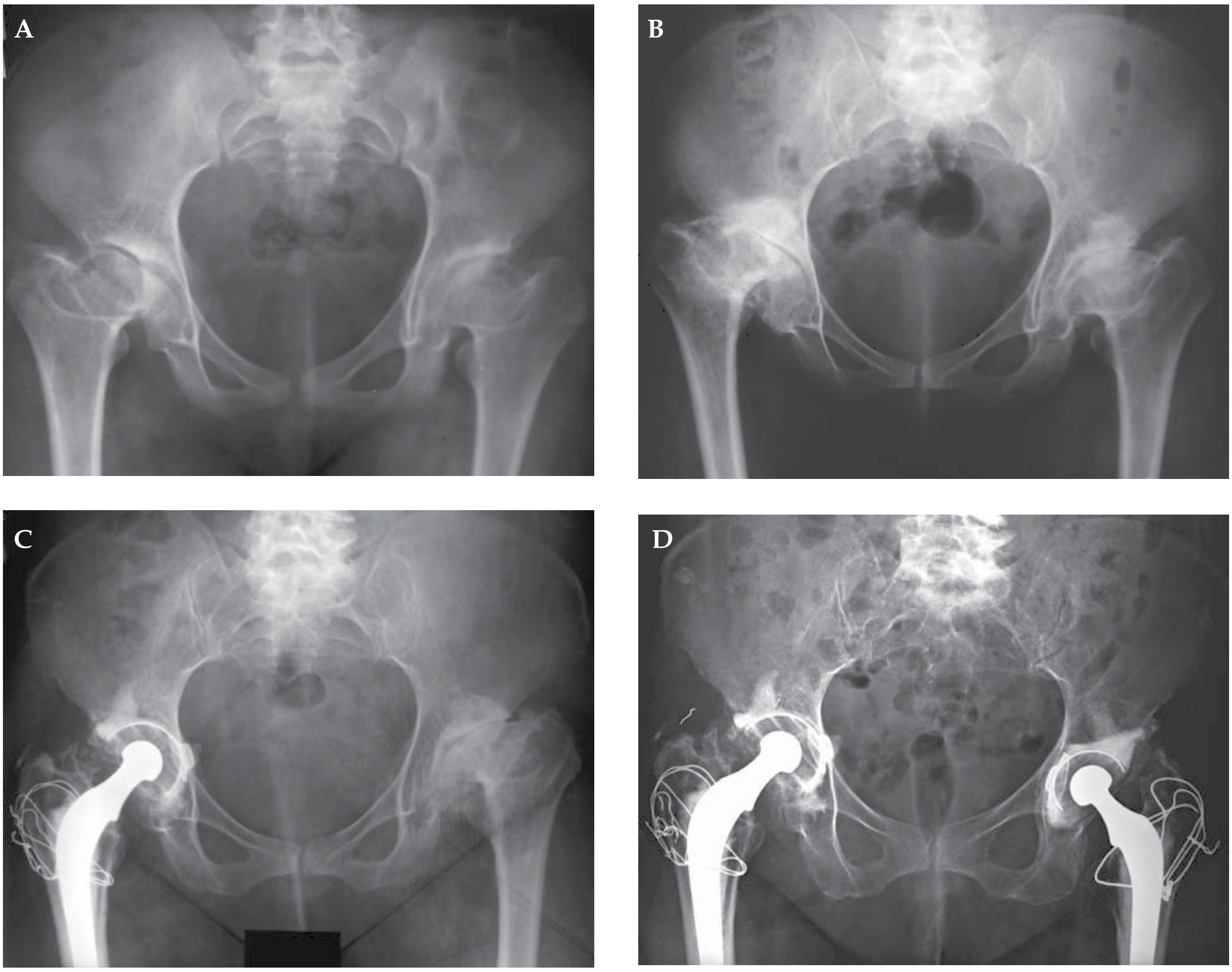

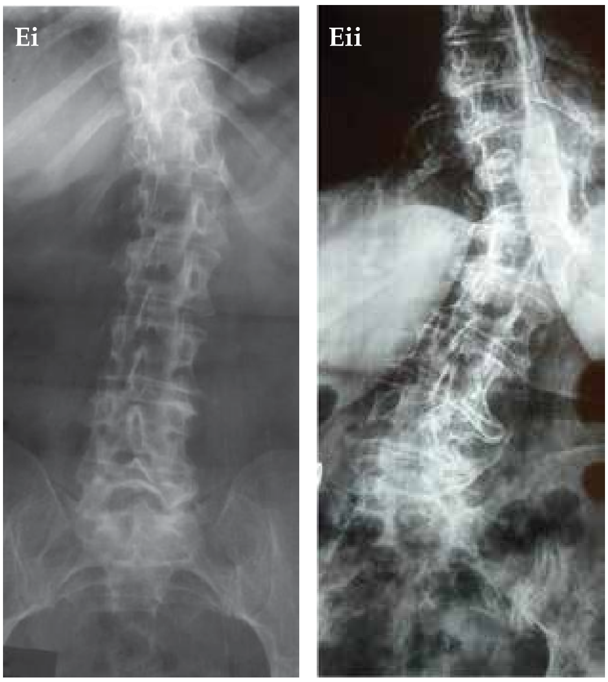

Fig. 2 *(a) The first available radiograph of the hips of a female patient at the age of 15 years. The bilateral hip dysplasia is obvious. The patient was limping but she had no pain. (b) Preoperative radiograph of the hips when the patient was 45 years old. (c) Postoperative radiograph of the right hip. (d) The latest follow-up radiograph 41 and 31 years after the initial operation of the right and left hip, respectively. (e) Lumbar spine radiographs, when the patient was (i) 58 and (ii) 86 years old. In recent years, the patient's main complaint is severe low back pain. Notice the great deterioration of the scoliosis deformity possibly because of the 10-year delay of the left THR because of patient's personal reasons.*

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the biomechanics of the artificial joint, and besides offer a wide exposure facilitating the creation of an artificial joint resembling as much as possible the normal joint. Bone cement was acting as a paste to fill the gap between the bone and the implants, rather than a glow, resulting in an elastic construction, in contrast to the rigid construction resulting when cementless components are used. Finally, the use of small diameter femoral heads, articulating with the thick ultra-high molecular weight polyethylene (UHMWPE) acetabular component resulted in a low frictional torque [7]. The original Charnley LFA, and generally cemented THR, has been modified several times as far as the components, bearing surfaces, and surgical technique are of major concern. One of the most effective modifications was the introduction of cross-linked polyethylene (HXLPE) decreasing considerably the rate of wear, and limiting the subsequent osteolysis and the loosening of the implants as presented by Glyn-Jones et al [13]. Another significant alteration during the years was the improvement of cementing technique (four generations of cementing technique) [14].

The senior author of the present study (GH) was started using the first generation of LFA at the Orthopaedic Department of the University of Athens, KAT Hospital, Greece, early in 1973, and continued using this method following its modifications introduced the next years. In 2015, he published with his colleagues the 30 to 40 years survivorship of 241 primary LFAs performed the period between 1973 and 1984 [15]. It is of interest that the survival rate of this series of consecutive hips operated in these early years, with revision for any reason or removal of the components as the end point, was 91% at ten years, 73% at 20 years, and 53% at 30 years when 40 hips still remained at risk. A common reason for failure during the first years of our experience was periprosthetic infection, and fracture of the stem. Of note, prophylactic antibiotics were not used in THRs performed until December 1977, and the risk of fracture of the stem was much higher when flat back stems with sharp corner from stainless steel were used, before the introduction of round-back stems from CoCr [15].

To the best of our knowledge, LFA is the only method with published data of 30 to 40 years survival. In 2009, Wroblewski et al [16] reported results from Wrightington Hospital, UK from 110 LFAs performed in 94 patients under the age of 65 years followed for more than 30 years. A total of 13 hips (12%) were revised for any reason at a mean follow-up of 32 years. In the same year, Callaghan et al [17], from the Iova University, published the updated results at a minimum of 35 years of 330 LFAs implanted by one surgeon in 262 patients. The average age of patients at the time of surgery was 65 years old (ranged, 29 to 86). A survivorship of 78% at 35 years was reported. The relatively lower survivorship of 53% at 30 years in our previously mentioned study [15] compared to these studies was probably due to the relatively high number of hips with CHD (31% of all hips) of whose most of them are considered challenging cases.

However, even in the favourable results of LFA, certain complications have been described using this early method of THR, such as polyethylene wear and the associated periprosthetic osteolysis leading to the aseptic loosening of the implants, implant failure/rupture, infection and dislocation [7, 18-20]. Additionally, THR attracted the attention of the industry because of its wide use that is increasing with the years [3-5]. For these reasons, researchers and industry started to develop new designs and techniques of THR with different materials of implants, bearing surfaces, biological cementless fixation methods, and minimally invasive surgical techniques [21, 22]. The transtrochanteric approach have been replaced with other approaches and minimally invasive surgery, the small 22.225 mm femoral head have been replaced by heads with greater diameter and the cemented implant fixation have been replaced in many cases by cementless fixation.

In the ’80s, and especially when the early aseptic loosening of cemented components was associated with the so called “cement disease” [23, 24], new designs of cementless THRs based on biologic fixation with bone ingrowth or ongrowth to obtain stability started to replace cemented THRs. However, since cementless THRs did not achieve to solve the problem of osteolysis and loosening [25],

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further studies highlighted the role of polyethylene debris and the related local macrophage response in osteolysis [26]. New bearing surfaces including new generations of ceramic-on-ceramic (CoC), metal-on-metal (MoM) and ceramic-on-polyethylene (CoP) started to develop [21, 22].

Soon, it was recognized that all bearing surfaces had advantages and disadvantages. More severe complications raised from the use of MoM designs. It was proved that MoM friction caused increased metal ions in patients serum and urine, metal hypersensitivity, pseudotumor formation, and a novel complication of aseptic, lymphocyte-dominated vasculitis-associated lesion (ALVAL) leading to increased rate of revision [27]. Few years later the product was recalled and many patients were asking to remove MoM implants [28].

For that reason, we should remember that there is not yet an ideal bearing surface and type of fixation of implants. Long-term clinical experience is the best way to lead our choice concerning the use of the surgical technique, implants and approach. Additionally, the type of prosthesis, bearing surface and implant fixation that is used mainly depends on the experience and the preference of the surgeon. The experience of the surgeon and the accurate surgical technique seems to play a primary role in the long-term survival of a THR.

It is of general agreement that THR is a successful and cost-effective operation, and has been considered as the operation of the century. However, it should be performed only after clear indication and "on time", meaning nether too early not too late. No operation can succeed if it is performed when not needed. The reported favorable long-term results do not only recognize the contribution of Charnley to the modern Orthopaedics but also help us to appreciate the causes of failure of the previous designs and reinforce our effort to create even better artificial joints. For this reason, there is a conviction that newer methods of THR promise even better results and there is a valid indication that THR is indeed the operation of the century.

Conflict of interest disclosure

The authors declared no conflicts of interest

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Hartofilakidis G, Lampropoulou-Adamidou K. The operation of the century almost half-century later Report of eleven total hip replacements survived 40 years and more. *Acta Orthop Trauma Hell* 2022; 73(1): 2-8.

Total hip arthroplasty in dysplasia and dislocation of the hip

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ABSTRACT

Developmental dysplasia of the hip encompasses a wide spectrum of hip pathology ranging from a shallow acetabulum to a completely dislocated "high-riding" hip. It is a common cause of secondary osteoarthritis and is the underlying diagnosis in the majority of young adults requiring total hip arthroplasty (THA) for coxarthrosis. It is clear we still do not have an agreed and correct terminology covering the entire pathology of congenital deformities of the hip. We recommend the use of the term "Dysplasia and Dislocation of the Hip (DDH)" that is by definition the most suitable term to describe the total spectrum of related deformities in adults. Various systems of classification of DDH in the adults are in use. The most practical classification seems to be that of Hartofilakidis et al. We propose a classification system of DDH in adults based on the CT of the pelvis to supplement the existing classification systems and to be used in the preoperative planning of a THA. The acetabular deficiency is classified, according to Crowe or Hartofilakidis classification, in the frontal plane based on a plain AP radiograph, and then further classified as "neutral", "anteverted" or "retroverted" in the transverse plane based on the CT scan of the pelvis. Careful attention to the morphology of the acetabulum, femur, pelvis, lumbar spine and knee in plain radiographs and CT scans in patients with DDH, is necessary, primarily to accurately classify the deformity and predict the bone deficiencies that will be encountered during THA. This will facilitate the selection of the proper reconstruction method and implants. In the present article useful surgical techniques and implants are presented for the management of these patients with a THA that presents difficulties because the majority of them are young with a considerable demand on their implants and they may require complex reconstruction on both sides of the joint.

KEYWORDS: total hip arthroplasty in developmental dysplasia of the hip, terminology of developmental dysplasia of the hip, classification of developmental dysplasia of the hip, reconstruction of the acetabulum, reconstruction of the femur

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Figure 1 *Classification of DDH in frontal and in transverse plane gives three-dimensional information of the hip, necessary to select the proper reconstruction method and implants. Examples of hips with (a) dysplasia, (b) low dislocation (B2 type), and (c) high dislocation (C2 type) according to Hartofilakidis classification, and (d) anteverted, (e) normal and (f) retroverted hips according to the proposed classification using CT imaging.*

Introduction

Developmental dysplasia of the hip encompasses a wide spectrum of hip pathology ranging from a shallow acetabulum to a completely dislocated "high-riding" hip. It is a common cause of secondary osteoarthritis and is the underlying diagnosis in the majority of young adults requiring total hip arthroplasty (THA) for coxarthrosis.

Hippocrates was well acquainted with this condition. In "De Articullis" he noted "Those suffer the greatest injury in whom, while still in the womb, this joint has been dislocated" and "However, it sometimes happens that an outward dislocation of both hips is found in one case from birth and in another as a result of disease". Dupuytren in 1826 wrote about the "Original or congenital displacement of the heads of the thigh-bones" when he observed some newborn infants with displacement of the head of the femur from the acetabulum [1]. Since then, the majority of authors have accepted the congenital nature of the deformity and used the term "Congenital Dislocation of the Hip" [2, 3].

Later the term "Developmental Displacement" was proposed because the disorder is of variable pathology, not always a dislocation, and even when dislocation occurs, it often happens postnatally, and therefore it is not truly congenital [4]. Many authors and the American Academy of Orthopaedic Surgeons accepted such concepts and used the term "Developmental Dysplasia of the Hip (DDH)".

Many disorders are, in that sense, developmental but the term is not used as part of the terminology.

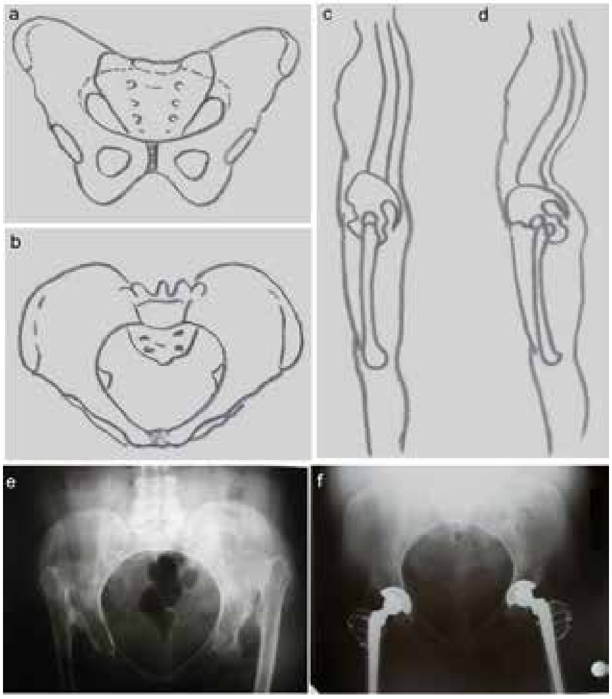

Figure 2 *In bilateral cases, the posterior shift of the femoral head increases the anterior tilt of the pelvis, which is compensated by hyperlordosis of the lumbar spine (a, c: normal; b, d: pathologic). Because of hyperlordosis, the pelvis is turned forward (d). In the plain AP radiograph, the pelvis can look like the "inlet view" (b). This structural deformity even without bony changes does not adequately improve after surgery despite the new location of the joints (e: preoperative radiograph, f: postoperative radiograph).*

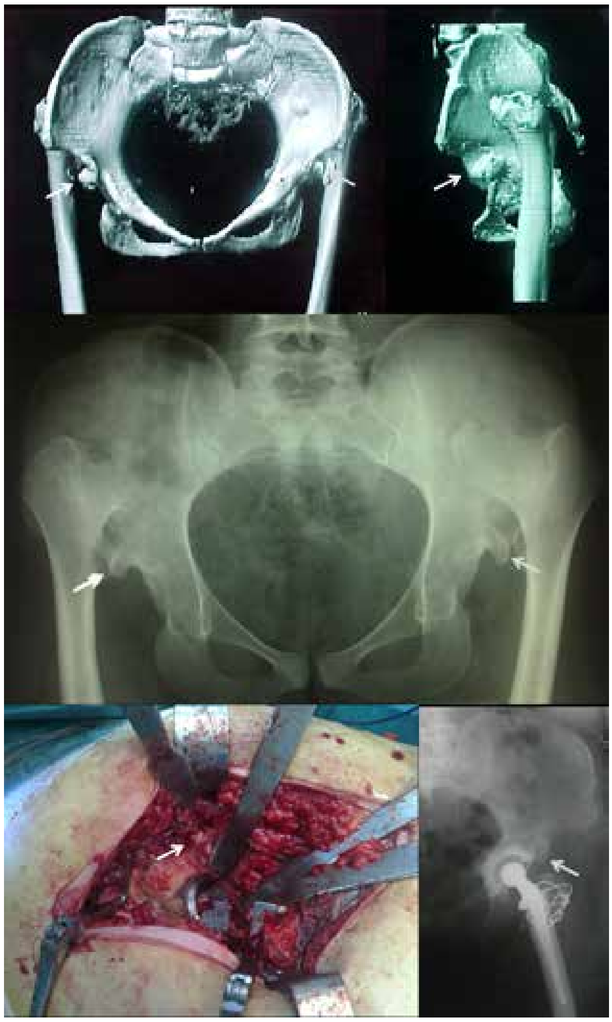

Figure 3 *As a rule, in high dislocation there is an anterolateral bony prominence beside the inferior iliac spine (arrows). This prominence in the plain AP radiograph can give the false impression of adequate bone at the weight-bearing area to achieve good coverage of the acetabulum, and in postoperative radiographs the cup can look too much medialized. This bony prominence is too anteriorly to offer any reliable anterosuperior support to the cup.*

That is why the term "Congenital Hip Disease" was recommended to substitute "Developmental Dysplasia" [5-8]. This term raised concerns because it is very general and it may include some other deformities (e.g., coxa vara, proximal femoral focal deficiency, femoral anteversion, epiphyseal dysplasia, etc.) that are also congenital hip diseases.

It is clear we still do not have an agreed and correct terminology covering the entire pathology of congenital deformities of the hip. Dysplasia by definition is an abnormality in form or development. Dysplasia comes from the ancient Greek words "δυσ-" or "dys-" meaning bad or difficult and "πλάσις" or "plasis" meaning formation. It is an ambiguous term used in pathology to refer to an abnormality of development or an epithelial anomaly of growth and differentiation (epithelial dysplasia). The terms hip dysplasia, fibrous dysplasia, renal dysplasia refer to an abnormal development at macroscopic or microscopic level. This term most commonly denotes a malformation of bone (e.g., epiphyseal dysplasia).

Development is the process of growth and

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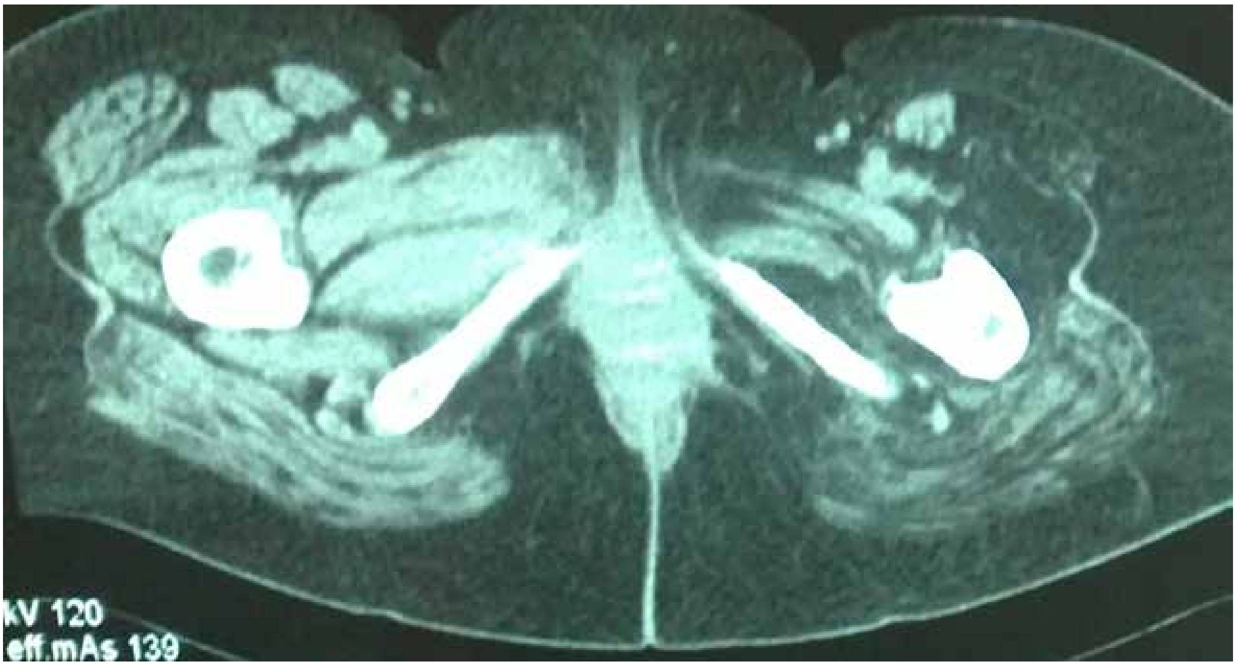

Figure 4 *The marked muscle atrophy around the left dislocated hip of this patient.*

Figure 5 *In the DDH, the ipsilateral knee has valgus deformity in order to maintain the axis of the leg. When THA is performed with placement of the cup to the true acetabulum (which lies more medial than the false acetabulum) the lateralizing effect of the femoral shaft can aggravate the valgus deformity of the knee. This is even greater in cases where medial protrusio technique is used.*

differentiation. The most crucial stage of human development occurs before birth, as tissues and organs arise from differentiation of cells in the embryo. This process continues until birth, and disruptions in development result in congenital types of diseases. The developmental process continues after birth, as an infant or child grows physically. Interruptions in any of these stages can result in developmental delay or abnormality.

The term "Developmental Dysplasia of the Hip" has by definition repetition of the word development (developmental abnormality in the development of the hip). According to the above "Hip Dysplasia" could adequately describe the total spectrum of related deformities (abnormality in form or development of the hip). This term includes both the congenital and developmental nature of the disease.

However, to avoid confusion and diagnostic inaccuracies, it is preferable for the term "dysplasia" to be reserved for the milder types of hip deformities, where the femoral head is within the badly formed (dysplastic) acetabulum. Therefore, the term "Dysplasia" is not suitable for cases with dislocation.

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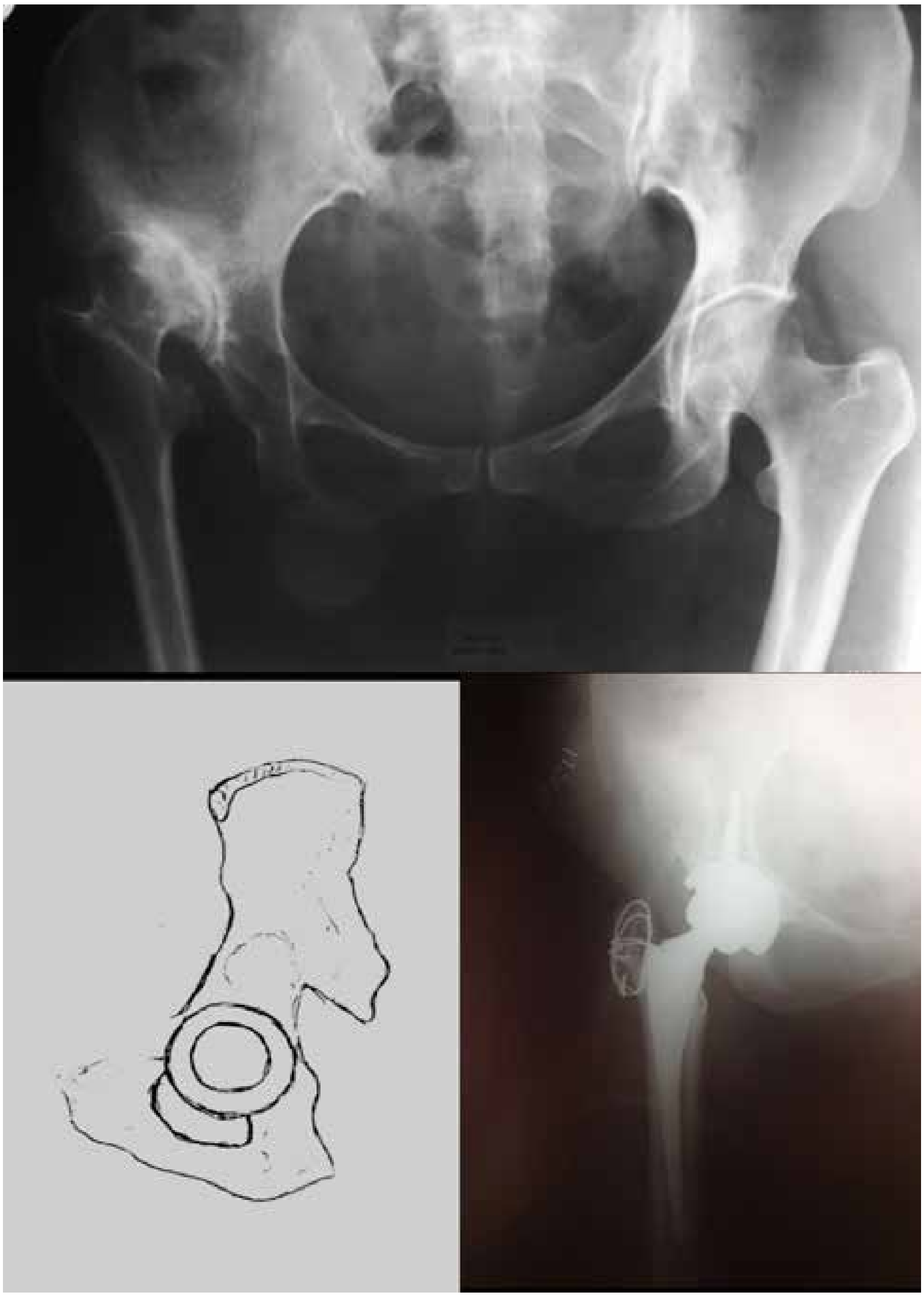

Figure 6 When the sagittal diameter of the true acetabulum is too small, the cup can be placed more inferiorly.

On the other hand, the need of a generally accepted term is obvious. It is clear that most orthopaedic surgeons will agree to use the most suitable term "Dysplasia and Dislocation of the Hip", reserving the term dysplasia for the milder types of hip deformities and then further classify the dislocated hips in low and high dislocation.

A suitable term would also be "Hip Dysplasia Disease or Syndrome". This term can cover the entire spectrum of the hip pathology of the disease in both adults and children. The term is also more suitable for authors from different specialties.

In conclusion, we recommend the use of the term "Dysplasia and Dislocation of the Hip (DDH)" that is by definition the most suitable term to describe the total spectrum of related deformities in adults

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Figure 7 *Oversized hemispherical cup. This method can be used in some cases of low dislocation where there is sufficient bone stock.*

(congenital and developmental, dysplasia and dislocation) and because in addition the abbreviation is the same as the current widely used term there will be a smooth passage to the new term.

Classification

Ideally, a classification system of DDH in addition to being reliable should validly predict the intraoperatively anticipated structural bone deformities or abnormalities, and aid treatment planning. Various systems of classification of DDH in the adults are in use. The most commonly used methods for evaluating dysplastic hips are based in radiographic findings that consider mainly the shape of the pelvis and the proximal femur.

The Crowe classification [9] is based on the degree of subluxation of the femoral head in relation to the acetabulum. Crowe et al. defined a four-stage system classifying the degree of dislocation in terms of the percentage of proximal displacement of the femoral head in relation to the height of the pelvis. Type I hips are those with less than 50% subluxation. Type II hips are those with 50 - 75% subluxation. Type III hips are those with 75-100% subluxation and type IV those with greater than 100% subluxation.

Eftekcar [10, 11] also recognized four types. Type A includes hips with dysplasia in which the acetabulum is dysplastic and slightly elongated. Type B and C include those with intermediate and high dislocation. The lower border of the false acetabulum identifies the roof of the original acetabulum. Type D includes hips with old unreduced dislocation whose the head has never been in contact with the ilium.

The Kerboul system [12] uses the anteroposterior position of the femoral head to grade the severity of hip dysplasia and classifies as anterior dislocation where the femoral head is located in front of the original acetabulum, intermediate dislocation, where the femoral head articulates with the ilium

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Figure 8 *Methods of acetabular reconstruction: (a) placement of the cup in the false acetabulum (lateralized position) (b) high hip centre without lateralization, (c) acetabular impaction grafting (cotyloplasty), (d) acetabular augmentation with structural graft, (e) oblong cup, (f) acetabular reinforcement rings.*

at the same anteroposterior level as the original acetabulum, and posterior dislocation where the femoral head is dislocated behind the original acetabulum.

Mendes et al. [13] and recently Gaston et al. [14] proposed a classification system for the adult dysplastic hip requiring THA.

The most practical classification seems to be that of Hartofilakidis et al. [8, 15, 16]. Hartofilakidis classification uses the pathology of the dysplastic acetabulum to classify DDH in three different types, identifying the true and the false acetabulum and the relation of the femoral head to these structures (Fig. 1). Type A hips are those with dysplasia, in which the femoral head is still within the true acetabulum. Type B hips are those with low dislocation in which

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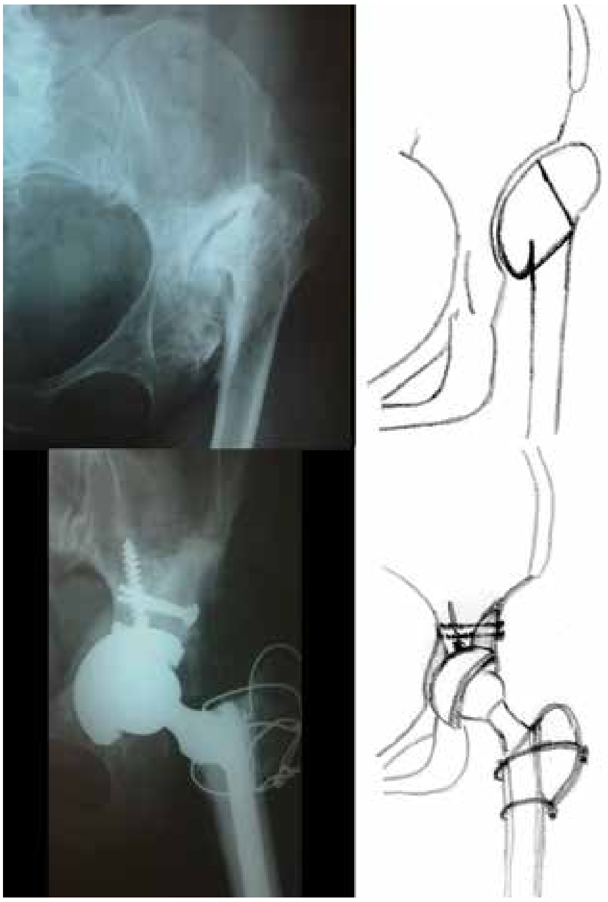

***Figure 9** Combination of cotyloplasty technique with minimal medial displacement and structural graft over the remaining uncovered acetabular component in a hip with low dislocation Hartofilakidis Type B2. Disadvantages of both techniques were avoided, and good coverage and position of the cup were achieved. The cup is not over medialized, most of the cup is in contact with host bone, and the defect that remains to be covered by the graft is less than one-third of the weight-bearing surface of the cup.*

the femoral head is in a false acetabulum, the inferior lip of which is in contact with or overlaps the true acetabulum. Type C hips are those with high dislocation, in which the false acetabulum has no contact with the true acetabulum.

Furthermore, Hartofilakidis et al. identified two subtypes of low dislocation: dislocation with extended or limited overlap between the false and the true acetabulum. When the coverage is extended (Type B1) the overlap between the false and the true acetabulum is more than 50%, and when the coverage is limited (Type B2) the overlap is less than 50%. In high dislocation, two subtypes were also identified: in Type C1, a false acetabulum is present, and in Type C2, there is no false acetabulum present and the femoral head is high-riding within the gluteal musculature.

Most of the traditional methods of analysis and classification for hip dysplasia and dislocation concentrate on a frontal-plane analysis of the hip. CT studies of the acetabular transverse plane anatomy showed that the dysplastic acetabula differ with respect to the location of dysplasia, some in the anterior position while others demonstrated just the opposite.

We proposed a classification system of DDH in adults based on the CT of the pelvis to supplement the existing classification systems and to be used in the preoperative planning of a THA [17]. The acetabular deficiency is classified, according to Crowe or Hartofilakidis classification, in the frontal plane based on a plain AP radiograph, and then further classified as “neutral”, “anteverted” or “retroverted” in the transverse plane based on the CT scan of the pelvis. Hips with hypoplastic anterior wall and excessive anteversion of over 30° were classified as “anteverted”. Hips, which, had a more or less normal distribution of bone stock and anteversion 0 - 30° were classified as “neutral”. Hips with the bone stock located anteriorly hypoplastic posterior wall and retroversion were classified as “retroverted” (Fig. 1).

Careful attention to the morphology of the acetabulum and femur in hip radiographs and CT scan in patients with DDH is necessary, primarily to accurately classify the deformity and predict the acetabulum bone deficiencies encountered during THA and to select the proper reconstruction method and implants.

Anatomy

Acetabulum

Hartofilakidis et al. [18, 19] have described in detail the acetabular and femoral morphological variations in the whole spectrum of DDH. Dysplastic hips present a gradually increasing deficiency of the

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Figure 10 *Resection arthroplasty (Girdlestone procedure) after infection of THA for a hip with low dislocation. The reconstruction performed with the use of structural graft and cotyloplasty technique.*

superior segment and a secondary shallowing due to the formation of an osteophyte that covers the acetabular fossa. In low dislocation, the inferior part of the false acetabulum is an osteophyte that begins at the level of the superior rim of the true acetabulum. The visible part of the true acetabulum has a narrow opening, anterior and posterior segmental deficiency and inadequate depth. In high dislocation, the true acetabulum is hypoplastic and triangular in shape. It has a segmental deficiency of its entire rim, a narrow opening, inadequate depth, and excessive anteversion is usual [18, 19].

The total iliac wing can be hypoplastic, anteverted and the bone stock at the area of the acetabulum has an abnormal distribution, mainly located superoposteriorly [19]. Several CT studies of dysplastic hips have implicated increased acetabular anteversion as one component of the anatomic deformity [20-22]. Others have not found acetabular anteversion to be consistently increased [22-25]. Excessive anteversion can be attributed to the hypoplastic anterior wall, anteversion of the iliac wing or both.

Retroversion of the acetabulum was found mainly after pelvic osteotomy in a younger age or conservative treatment with plaster or traction. Anterolateral rotation, posterior deficiency of the acetabulum and inadequacy of posterior coverage was found after Salter, triple, Chiari and Bernese osteotomy [26-34] because anterolateral coverage is gained at the expense of posterior coverage, by virtue of the rotational redirection of the acetabulum. Interestingly hips, which had undergone additional femoral derotational osteotomies were associated with significantly more pronounced acetabular retroversion [35].

Femur

Even in the most mildly dysplastic hips, the femur has a smaller canal and are more anteverted in comparison with the normal. With increased subluxation, additional abnormalities are observed in the size and position of the femoral head. The size and shape of the human femur, however, vary with the gender, age, stature and ethnic background of the individual and it is difficult to isolate the effect of dysplasia on its shape. The degree of subluxation of the hip also leads to significant alterations in the shape of the femur because of profound changes in the magnitude and direction of the joint reaction forces.

In the dysplastic hip, the femoral head is initially spherical but gradually becomes elliptical and elongated, due to the formation of marginal osteophytes. The femoral neck and the diaphysis are within the range of normal anatomy. In low dislocation, the femoral head, also due to the formation of marginal osteophytes, is often large

Figure 11 *Acetabular component loosening after THA for low dislocation. The acetabular component was placed in the false acetabulum. The femoral component penetrates the femur posteriorly. The revision, in this case, is difficult because of the destruction of valuable bone at the weight-bearing area. The reconstruction included the use of structural allograft for the acetabular defect and the performance of extended trochanteric osteotomy with the placement of a long stem for the femur.*

and elliptical. Occasionally, the femoral neck is anteverted, and the diaphysis is narrow. In high dislocation, the femoral head is small and non-spherical. It either articulates with a false acetabulum or moves freely within the gluteal muscles. The femoral neck always shows increased anteversion, and the lesser trochanter lies more anteriorly than normal. The diaphysis is hypoplastic with thin cortex and extreme narrowing of the canal [18, 19]. The presence or absence of a false acetabulum in high dislocated hips is associated with different loading patterns and influence the development and shape of the proximal femur. In the latter type, the deformity of the femur is greatest among all types of DDH.

It is widely believed that coxa valga is typically present in the femur of hips with DDH. However, in morphometric studies, there was no significant difference in the neck-shaft angle of dysplastic and normal femur [36, 37]. On the contrary, the mean

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Figure 12 *Acetabular component loosening after placing the cup in the false acetabulum. The revision of these cases is difficult because of the destruction of the valuable bone during the index operation. The reconstruction performed using structural graft and cotyloplasty technique.*

inclination of the femoral neck decreased slightly with increasing severity of subluxation and therefore there were significantly more cases of coxa vara in patients with high dislocation than in the normal [36, 37]. The impression that the femur in DDH has a more valgus neck inclination is probably due to the normal effect of anteversion on the appearance of the proximal femur as projected on a standard AP radiograph. As the neck of the average DDH femur is orientated at 35° to the coronal plane, the AP radiograph gives an oblique view of the proximal femur, with significant foreshortening of the neck [36].

The length of the femur can be equal, shorter or longer than the other femur. In the unilateral cases, the femur may be longer than it is at the normal side but the leg is shorter due to the dislocation. Rarely the tibia can also be longer in unilateral cases. This is important when dealing with limb length discrepancy and when planning a shortening osteotomy.

Various studies show that the shape of the femur in DDH becomes more abnormal with increasing subluxation [36-38] The morphologic heterogeneity across the levels of hips with DDH suggests that the femoral prosthesis is difficult to be chosen based exclusively on the severity of the subluxation.

Lumbar spine and pelvis

In unilateral cases, leg length discrepancy leads to secondary scoliosis. These structural deformities of the pelvis and the spine may create a new imbalance of the hips and the posture of the trunk, especially if leg length is fully corrected. This is one of the most critical parts of the surgical treatment of these, usually young females, who consider their leg length discrepancy as their major problem and often causes considerable psychological effects.

In bilateral cases, the posterior shift of the femoral head increases the anterior tilt of the pelvis, which is compensated by hyperlordosis of the lumbar spine. Because of hyperlordosis, the pelvis is turned forward. In the plain AP radiograph, the pelvis can look like an “inlet view” (Fig. 2). Because of that, the weight-bearing area of the acetabulum is moving superoposteriorly, where the bone stock is usually located, and the gluteus medius musculature runs cephalad instead of laterally.

This structural deformity, even without bony changes, does not adequately improve after surgery despite the new balance of the joints. Appropriate modification of the socket and orientation in the functional position of the pelvis is indicated in both deformities. These deformities are also likely to cause chronic low-back pain.

As a rule, in high dislocated hips, there is

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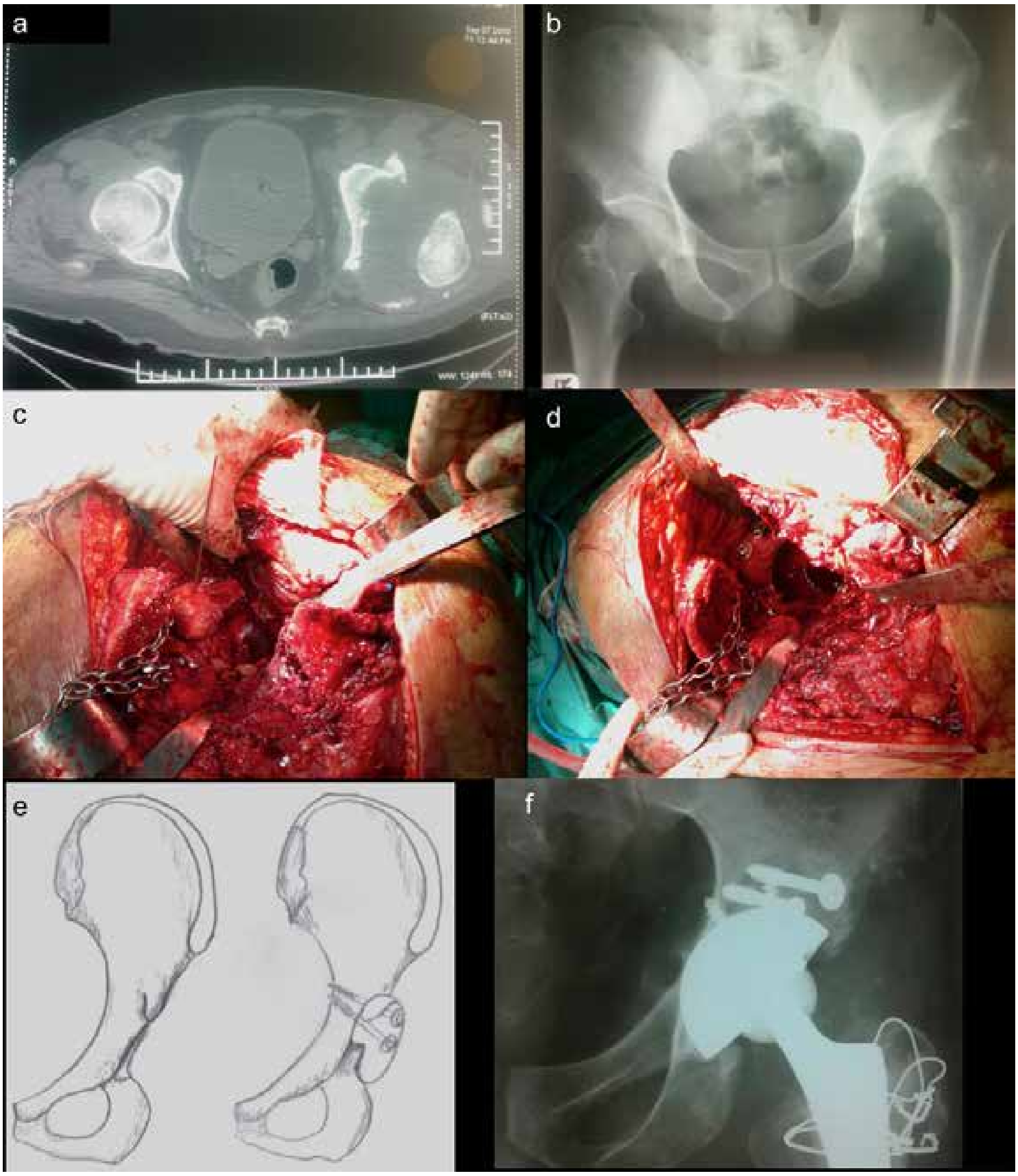

Figure 13 *(a, b) Retroverted hip. Complete absence of the posterior wall. This was the result of a fracture of the posterior wall and posterior dislocation of the femoral head that was left untreated in a younger age. (c-f) The resected femoral head and the neck segment are used for reconstruction of the posterior and upper part of the acetabulum.*

an anterolateral bony prominence beside the inferior iliac spine. This prominence in the plain AP radiographs can give the false impression of adequate bone at the weight-bearing area, and in postoperative radiographs, of a medialized position of the cup (Fig. 3). In CT studies and during surgery, it became clear that this bony prominence is too anteriorly to offer any reliable anterosuperior support to the cup. This prominence can be used as a structural graft if needed.

Soft tissue contractures

The abductor, adductor, iliopsoas, hamstrings and rectus femoris muscles are usually shortened

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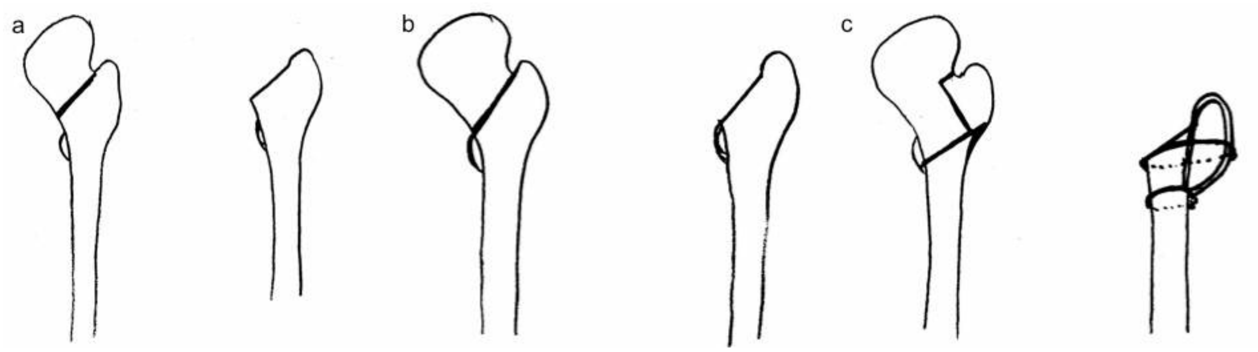

***Figure 14** The level of resection of the femur is estimated with x-ray templates. (a) In hips with dysplasia (Hartofilakidis Type A) and low dislocation (Hartofilakidis Type B1), an ordinary stem may be used. (b) If there is too much anteversion, a cut at the level of the lesser trochanter is needed to correct the version. (c) In hips with low (Hartofilakidis Type B2) and high dislocation (Hartofilakidis Type C), a transverse trochanteric osteotomy is usually required. In high dislocated hips, the femoral component must be mounted below the intertrochanteric level. At this level, the diaphysis is straight and narrow. Therefore, a small straight DDH stem is required.*

and hypoplastic (Fig. 4). The fixed contractures of the soft tissues must be released by tenotomy, fasciotomy and capsulectomy in order to perform a hip arthroplasty. Sometimes subcutaneous adductor tenotomy must be performed in order to relieve too much tension after reduction of the stem to the acetabulum. In the most difficult cases, it can be done before the limb is prepared and draped to facilitate the reduction of the hip during THA.

Knee

In DDH, the ipsilateral knee, in some cases, has an excessive valgus deformity in order to maintain the axis of the leg. When the hip arthroplasty is done with placement of the cup to the true acetabulum, which lies more medial than the false acetabulum, the lateralizing effect of the femoral shaft can aggravate the valgus deformity of the knee (Fig. 5). The valgus knee can cause adduction of the leg with the risk of dislocation. In such a case, the valgus knee should be restored with an osteotomy or a total knee replacement depending on the age of the patient and the stage of osteoarthritis of the knee.

Careful attention to the morphology of the acetabulum, femur, pelvis, lumbar spine and knee in plain radiographs and CT scans in patients with DDH, is necessary, primarily to accurately classify the deformity and predict the bone deficiencies that will be encountered during THA. This will facilitate the selection of the proper reconstruction method and implants.

Treatment

Dysplasia and dislocation of the hip (DDH) is a disorder that results in anatomic abnormalities leading to increased contact pressure in the joint and, eventually, coxarthrosis. However, many patients with DDH become symptomatic before the development of severe degenerative changes because of abnormal hip biomechanics, mild hip instability, impingement, or associated labral pathology. Several non-arthroplasty surgical treatment options are available [39].

Because in many hips the main deformity is acetabular, a reconstructive osteotomy that restores more nearly normal pelvic anatomy is preferred. The Bernese (Ganz) periacetabular osteotomy (PAO) is currently recommended because it provides satisfactory correction while creating limited secondary pelvic deformity or destabilization of the pelvis [40]. Proximal femoral osteotomy is sporadically needed as a supplement to pelvic osteotomy and may also be indicated as an isolated procedure when the dominant deformity is located on the femoral side (coxa valga subluxans). Arthroscopy can be beneficial when symptoms seem

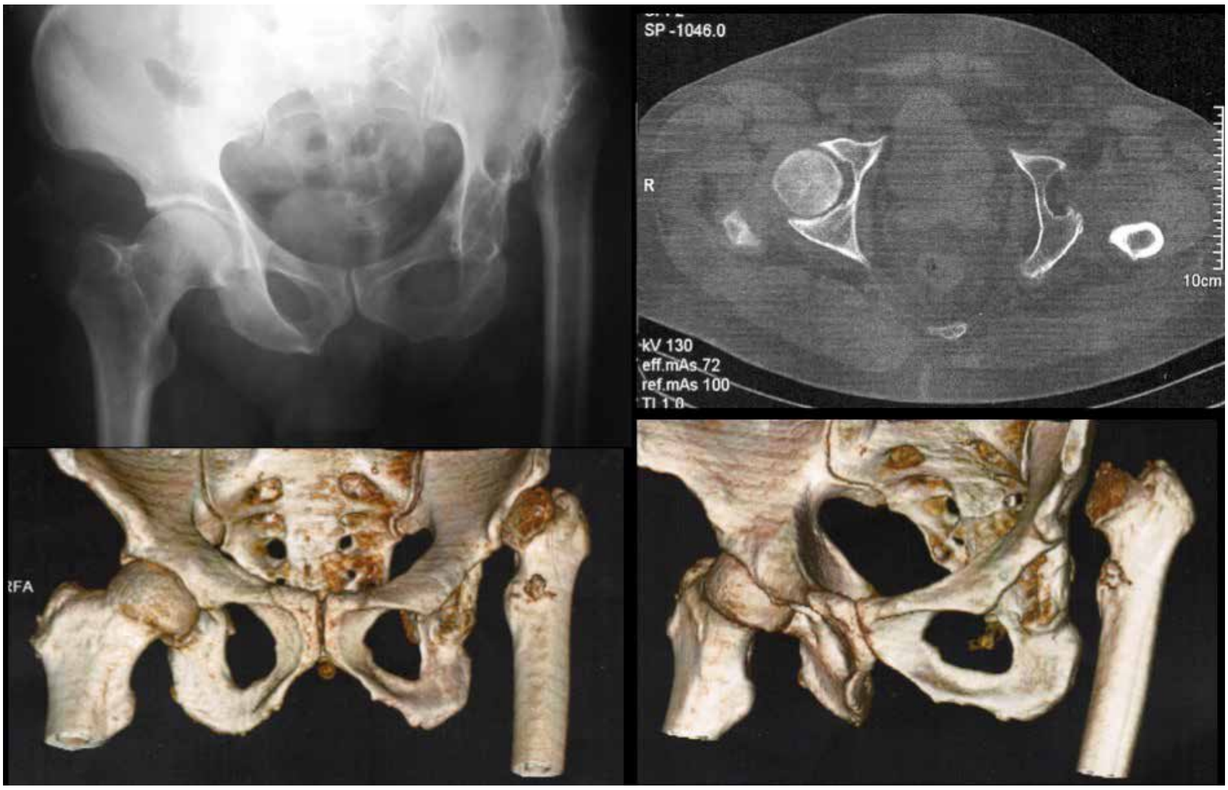

Figure 15 The use of hip radiographs and CT/3DCT scan can accurately classify the deformity and predict the acetabulum bone deficiencies in order to select the proper reconstruction method and implants according to the type of DDH.
In this case, the hip can be classified as Type C2 N (high dislocation without false acetabulum and normal anteversion). Perform transverse trochanteric osteotomy. Place the acetabular component within the true acetabulum. Small components make the procedure easier.

to be related only to labral tears or loose bodies in the absence of severe structural abnormalities of the hip. Fusion or “resection” arthroplasty are rarely indicated and are reserved for particular patients who are not candidates for total hip “replacement” arthroplasty (THA) or other procedures but who complain of intense hip pain [39].

The management of these patients with a THA presents difficulties because the majority of them are young with a considerable demand on their implants and they may require complex reconstruction on both sides of the joint.

Surgical approach

Hartofilakidis Type A and Type B1 hips can be approached through a conventional posterior, anterior or lateral approach without disturbing the greater trochanter unless the trochanter is riding high due to previous avascular necrosis of the femoral head. Under those circumstances, the surgeon may elect to perform a trochanteric osteotomy in order to advance the greater trochanter distally [41]. Hartofilakidis Type B2 and Type C hips may require a more elaborate approach in order to obtain extensive pelvic exposure and to advance the greater trochanter if indicated. A trochanteric osteotomy provides excellent pelvic exposure. It allows the surgeon to identify the false and true acetabula and, if necessary, to reconstruct the acetabulum. A trochanteric osteotomy also allows easier lengthening of the extremity [41].

A transverse osteotomy in which the vastus lateralis is dissected off the greater trochanter offers the best pelvic exposure but carries the

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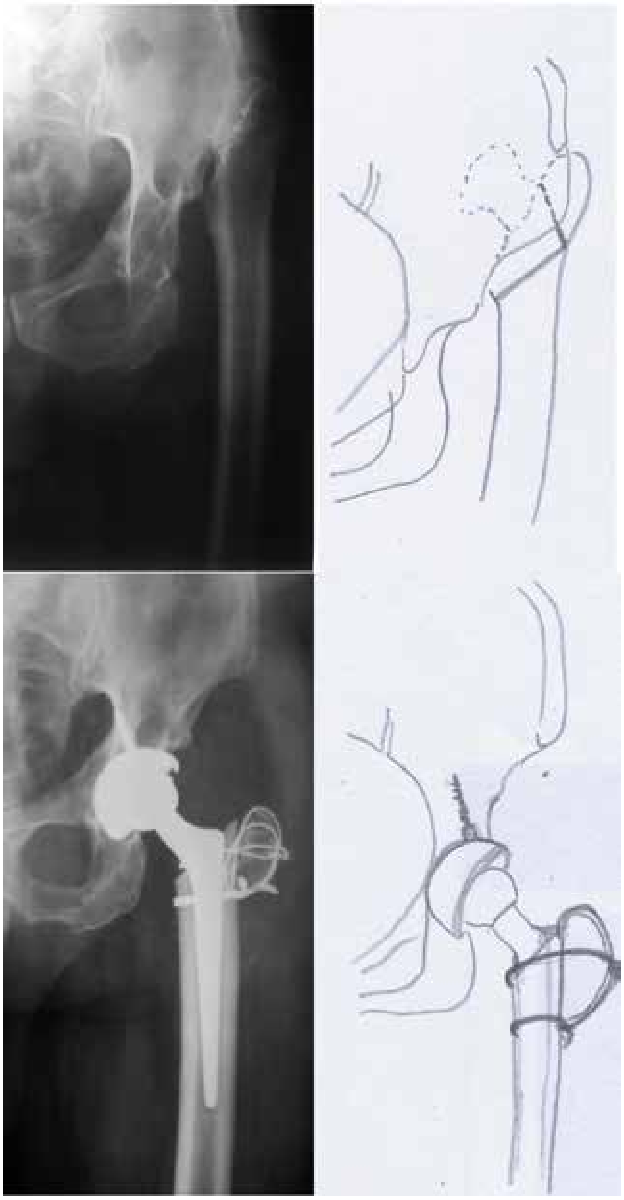

Figure 16 The same case: high dislocation Type C2 N. The level of resection of the femur was estimated just below the intertrochanteric level. At this level, the diaphysis is straight and narrow. Transverse osteotomy of the trochanter and proximal shortening of the femur were performed. Therefore, a small straight DDH stem is required. The stem was rotated to the correct anteversion. Small components and straight stem were used. No additional reconstruction method was needed.

risk of nonunion and trochanteric migration. A trochanteric slide osteotomy retains the attachment of the vastus lateralis, which protects against trochanteric migration, but the exposure is not as good as with the transverse osteotomy, and if the leg is lengthened, it is necessary to keep the trochanteric fragment long in order to ensure bone-to-bone apposition for healing [42].

A subtrochanteric osteotomy that is performed for femoral shortening and derotation can also be used for the exposure, allowing preservation of the greater trochanter while still providing good pelvic exposure for bone grafting. If a trochanteric osteotomy has already been performed, special care is needed to preserve the blood supply and muscular attachments to the femur proximal to the subtrochanteric osteotomy [43, 44].

When the hip is initially exposed, the femoral head is dislocated from the false acetabulum, and the site of the true acetabulum may not be immediately apparent. Using the thickened and elongated joint capsule as a guide can identify the true acetabulum. When the true acetabulum is exposed, a retractor is placed inferior to the transverse ligament and into the obturator foramen to ensure that the dissection has been carried far enough inferior. The depth of the acetabulum often is deceptive because it is filled with bone. Removal of the pulvinar exposes the depth of the cotyloid fossa and the medial wall of the acetabulum and allows the surgeon to determine the amount of medialization that can be accomplished by reaming. If the fossa is not apparent, a hole can be drilled, and a depth gauge is used to determine the thickness of the available bone. Absence of superior, anterior (Anteverted Hips) or posterior (Retroverted Hips) wall of the true acetabulum may be noticed at this stage of operation, and they should be developed during the reaming process.

Reconstruction of the acetabulum

The major technical difficulties encountered in a THA for DDH are during the reconstruction of the acetabulum and remains a significant challenge in modern joint reconstruction surgery. Placement of the cup depends on the amount of available bone stock and the magnitude of the limb length discrepancy and differs in the various types of

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the dislocation. Problems arise in some cases with low dislocation when the upper half of the true acetabulum is overlapped by the false acetabulum (Hartofilakidis Type B2), some cases with high dislocation (Hartofilakidis Type C), and when there is posterior wall deficiency (Retroverted hips).

Most authors recommend placement of the acetabular component within the true acetabulum. This medial and inferior location diminishes joint contact forces, facilitates limb lengthening and improves abductor function. Furthermore, fixation of the cup in the false acetabulum can be difficult because bone stock in that area, where the iliac wing is thin, is insufficient.

In cases in which the reamed acetabulum can provide osseous cover of at least 80% (as it is estimated intraoperatively) an uncemented acetabular component is preferred [19, 45]. If the sagittal diameter is too small at this level, the cup can be placed more inferiorly (Fig. 6). The size of these components is often small, and in order to avoid problems with thin polyethylene liners [46], some authors currently advocate the use of monobloc components or alternative bearing surfaces such as ceramic-on-ceramic [47]. These techniques also have the advantage of using a bigger femoral head.

Excellent clinical results have been reported using standard or oversized hemispherical cups to reconstruct the acetabulum defects in revision hip arthroplasty by converting the deficient acetabulum back into a hemisphere with an intact rim of bone [48-50]. This method can be used in some cases of low dislocation where there is sufficient bone stock (Fig. 7).

However, if the acetabular defect is large and the bone stock is insufficient; small, standard or oversized hemispherical cups might not achieve adequate stability on host bone, and alternative methods of acetabular reconstruction are necessary. Several techniques are in use such as placement of the cup in a high hip center with or without lateralization, acetabular impaction grafting (cotyloplasty), acetabular augmentation with structural graft, and the use of oblong cups or acetabular reinforcement rings (Fig. 8).

One of the most popular reconstruction methods of a deficient acetabula involves structural graft from the femoral head. The use of a bulk structural autogenous graft from the femoral head to augment the superolateral aspect of the acetabular rim was initially proposed by Harris et al. [51] and is advocated by many authors. This technique can restore the bone stock for future revision surgery, the hip center, and the limb length [52, 53]. Excellent short to mid-term results have been published [54-60], while others reported marked resorption of the graft [61] and rates of loosening as high as 46% after 12-year follow-up [49, 62].

The reason for such a high failure rate may be the abnormal distribution of stresses combined with the unfavorable long-term biological behavior of structural grafts [61, 62]. Most of these reported long-term results have been in conjunction with cemented acetabular components. Theoretically, uncemented cups may have a better outcome than cemented cups because of better transmission of forces. It is likely that the success of the graft is owed in part to the quality of the initial fixation and the accurate apposition of the graft to the pelvis.

Some authors have recommended the placement of a small socket in a high but not a lateral position (high hip center) [49, 63, 64]. Although the effect of a high hip center on the durability of the arthroplasty remains controversial, there is enough evidence for increased rates of femoral and acetabular loosening with initial acetabular cup positioning outside of the true acetabular region. Other authors have argued that isolated superior placement of the cup, without concomitant lateral displacement, is not detrimental to prosthetic component longevity. The advantage of this technique is the ability to place a cementless cup against bleeding host bone. The disadvantages are less bone stock for subsequent revision surgery, and if there is great limb length discrepancy the lengthening of the leg must be done on the femoral side and there is always a higher risk of impingement and dislocation [65-68].

There are two techniques in order to place a small cup in a protrused position. The first is to ream the floor of the true acetabular fossa (medial protrusio technique). The other is an acetabuloplasty technique which involves the creation of a controlled comminuted fracture of the medial wall of the acetabulum, the placement autogenous cancellous morselized bone graft on the periosteum and between the fragments, and the insertion of a cemented cup. This technique was developed by K. Stamos and was named acetabular impaction grafting or cotyloplasty [15, 16, 45]. This technique can also be used with the placement of an uncemented cup. Hartofilakidis et al reported satisfactory mid- and long-term results of the original cotyloplasty technique [16, 45]. Comparable good long-term results have been reported by other series [69-71].

Both of these techniques re-establish the hip center. The first technique has yielded good results when an uncemented cup was used but poor when a cemented cup was inserted [63]. When the hip is placed in a protruded position better coverage of the cup superiorly, and also better coverage anteriorly and posteriorly can be achieved. The medial placement of the component also reduces the abductor force needed to balance the pelvis. Care must be taken to avoid excessive medialisation because of impingement. This is aggravated even more by the valgus deformity of the knee (Fig. 5). The intentional perforation of the medial wall and associated removal of bone stock may compromise later revision procedures.

The oblong type cups provide another alternative for acetabular reconstruction. These cups have been used mainly for revision arthroplasty of the acetabulum, and they have been advocated for primary replacement in hips with low and high dislocation. The oblong cup was designed to provide implant stability on host bone and to restore the anatomic hip center [72]. The primary disadvantage associated with the use of this device for treatment of hips with DDH is not only the failure to restore bone stock but the distraction of what valuable bone stock there is. In the published short-term results, complications such as acetabular stress fracture and loosening have been reported [73, 74].

Another option for the reconstruction of the defected acetabulum in DDH is the use of bone grafts and antiprotrusio cages along with cemented polyethylene cup. Some authors advocated the use of such cages with bone graft after the good results that these cages had in cases of revision arthroplasty in comparison with the use of bone graft alone [75]. These implants require an extensive exposure in order to secure the implant's iliac and ischial extensions. The results using this technique are controversial [75-81]. We reserve these last two techniques for revision surgery of DDH in older patients.

Finally, in cases with significant bone stock deficiency superiorly, where the structural graft will support almost entirely the cup or by using the medial protrusio technique the cup must be medialized too much, the combination of medial protrusio technique with minimal medial displacement and structural graft over the remaining uncovered acetabular component can avoid the disadvantages of both techniques and get good coverage and position of the cup (Fig. 9). The cup is not over-medialized, and the most of the cup is in contact with host bone. The defect that remains to be covered by the graft must be less than one-third of the weight-bearing surface of the cup. Combination of these techniques can also be used in revision cases of DDH (Fig. 10, 11, 12).

Special attention is needed in cases of retroverted hips. Retroverted hips are usually iatrogenic and result after pelvic osteotomy. Care must be taken during the reaming process not to destroy the posterior wall. If needed the resected femoral head and neck segment is used for reconstruction (Fig. 13). Pelvic osteotomy can help THA in the adult by providing a better bone stock of the weight-bearing area. However, in cases with misdirection of the osteotomy and posterior wall deficiency, THA is even more complicated than in hips, which receive no treatment at all.

Reconstruction of the femur

Because of the anatomical abnormalities of the dysplastic femur, it is widely believed that if THA is performed using conventional designs of femoral prostheses, the centre of the femoral head will not be restored to an acceptable position. This has led to the increased use of customised prostheses and

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the emergence of implants specifically designed for DDH. Since the anatomical abnormalities present are thought to increase with the severity of the deformity of the hip, difficulty in performing joint replacement and the use of appropriate design of a femoral prosthesis may be related to the severity of the disease and its effect on the morphology of the dysplastic femur.

In dysplastic hips, and in the majority of hips with low dislocation, the reconstruction of the femur is similar to that of conventional cases. Problems arise with the more hypoplastic types of low dislocation, in hips with high dislocation, and in hips where previous femoral osteotomies have been performed.

The neck cut must be made at the level of the lesser trochanter. It is necessary because cutting the neck short decreases the degree of neck anteversion allowing for easier insertion and fitting of the femoral component. Excessive femoral anteversion can also be corrected with a straight and narrow stem, a modular femoral component, or a cemented stem that can be rotated into any degree of version. A trial reduction is then attempted after release of the iliopsoas tendon and the small external rotators. If the reduction is not possible, additional shortening of the femur is needed (Fig. 14). Additional shortening of the femur can also be needed because the femur might be longer than the other especially in the unilateral cases.

Femoral shortening can be carried out by means of subtrochanteric osteotomy [43] or by resection of more bone from the proximal part of the femur [82]. Shortening can also be achieved by distal femoral osteotomy [83]. In this way, a valgus knee can be corrected at the same time, if needed.

A subtrochanteric shortening osteotomy offers maximal bone preservation and does not require an additional incision or hardware but is associated with the potential problem of nonunion. A long stem or a modular stem may be necessary to provide stable fixation of the osteotomy site. A step-cut, oblique or chevron osteotomy, cortical struts, or a plate can be used to obtain stability at the osteotomy site [84] [85] [86] [87] [88] [89] .

A step-cut, oblique, or chevron osteotomy is technically difficult and requires adjusting the version while allowing for the configuration of the osteotomy. Special design modular femoral components are easier to use if the femoral shortening is carried out by subtrochanteric osteotomy and an uncemented stem is used.

Shortening by resection of more proximal femoral bone avoids the problems associated with osteotomy but involves the resection of metaphyseal bone, which is needed for stabilisation of the implant and osseous ingrowth. However, proximal shortening is more simple and uneventful. Though, care must be taken to keep the resection proximal enough otherwise the narrow diameter of the femoral canal more distally may become a major problem. To overcome this problem, splitting of the femur both anteriorly and posteriorly before the medullary canal is prepared and filling the splits with cancellous bone has also been proposed but specially designed femoral components with very thin straight stems are now available, and there is no need for that technique [90].

Short cementless conical distal bearing components and custom-made femoral components have also been used. If a trochanteric osteotomy was advocated, the greater trochanter must be shaped concave to fit on the proximal diaphysis of the femur and advanced distally far enough. Rarely, in very dysplastic cases, a two-level osteotomy is required to reduce the joint and equalise leg-lengths.

Sciatic and femoral nerve

Although some authors prefer lengthening of the leg with the use of external fixation prior to THA, most authors prefer lengthening at the time of surgery. Lengthening of the leg can cause sciatic nerve damage. Although the lengthening of the leg is not directly proportioned with the possibility of damage to the nerve [91, 92], if the limb is to be lengthened by more than 2 cm, it is wise to identify the nerve in order to check its tension after trial reduction is done and protect it during surgery. Excessive dissection of the nerve should be avoided because of the danger of devascularization. Some authors proposed wake-up test [93] or monitoring of the nerve with somatosensory evoked potentials [94].

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The femoral nerve can also be damaged during surgery either by too much lengthening or more often by the correction of fixed flexion deformity. Care must be taken not to damage the nerve with the anterior retractor because the nerve is sometimes too close to the anterior wall of the false acetabulum.

The postoperative position of the leg should be with the hip flexed to relax the femoral nerve and the knee flexed to relax the sciatic nerve. Stretching of both hip and knee is then done gradually. Since we have been using this technique, neuropraxia was avoided. However, in cases of neuropraxia due to lengthening of the leg after THA, patients usually recover within 6 months postoperatively.

In conclusion, careful attention to the morphology of the acetabulum and femur in hip radiographs and CT scan, accurate classification of the deformity, selection of proper reconstruction method and implants, and surgical experience are essential in order to be effective in treating this condition.

Tips and tricks

Use both hip radiographs and CT scan preoperatively to accurately classify the deformity and predict the acetabulum bone deficiencies (Fig. 15). Perform transverse trochanteric osteotomy in most cases with low and high dislocation. Placement of the acetabular component within the true acetabulum diminishes joint contact forces, facilitates limp lengthening and it improves abduactor function. The use of small components can make the procedure easier (Fig. 16). If needed, cotyloplasty technique or Harris graft, is used to achieve adequate acetabular coverage (Fig. 8, 9).

Femoral shortening can be carried out by means of subtrochanteric osteotomy or by resection of bone from the proximal part of the femur. Unless there is a femoral curve that needs correction, proximal shortening is more simple and uneventful. The level of resection of the femur is estimated with x-ray templates. In dysplastic and low dislocated hips, an ordinary stem may be used. In high dislocation, the femoral component must be mounted below the intertrochanteric level. At this level, the diaphysis is straight and narrow. Therefore, a small straight DDH stem is required. Place a wire just below the intertrochateric area for two reasons: first to avoid the periprosthetic fracture when impacting the stem because the cortex is very thin, and second to hold the tension band wire for the great trochanter reattachment (Fig. 14c). Passing the tension band wire within the medullary canal with the stem in place may be impossible because the diaphysis at this level may be too narrow.

Full correction of the leg length discrepancy is indicated only in younger patients with mobile lumbar spine. After reduction and closure, a subcutaneous adductor tenotomy is required if there is too much tension. If significant leg-lengthening has been performed, it is wise to place the patient with the hip and knee flexed postoperatively in order to relax both femoral and sciatic nerve. Stretching of both hip and knee is done gradually. In difficult cases, full weight-bearing is restricted for three to six weeks postoperatively.

Conflict of interest disclosure

The author declared no conflicts of interest.

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REVIEW

Current trends and controversies in femoral head osteonecrosis

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ABSTRACT

Osteonecrosis of the femoral head is a disabling disease with necrosis of bone and bone marrow occurring within the head that predictively leads to collapse of the subchondral infract if left untreated. Osteonecrosis can be either traumatic or non-traumatic associated with an array of systemic diseases and risk factors and frequently presents a multifocal distribution. Corticosteroids are considered a risk factor for osteonecrosis. Patients treated for myelogenous diseases and COVID-19 are particularly in elevated risk for developing osteonecrosis. At an early stage it is asymptomatic and undetectable in simple radiographs. MRI is the gold standard for diagnosis and should be prescribed early after corticosteroid therapy. Therapy is, in most cases, surgical and every attempt should be made to preserve the native joint in young patients. If articular surface collapse is established, total hip arthroplasty is the treatment of choice to maintain the quality of patients' life.

KEYWORDS: osteonecrosis; femoral head; MRI; corticosteroids; COVID-19

Introduction

Osteonecrosis (ON), also known as avascular necrosis (AVN), is defined as a pathologic process that results from a crucial disruption of blood supply to a bone segment, which usually results in the structural collapse of the osteonecrotic lesion, leading to osteoarthritis of the hip joint requiring total hip replacement [1, 2, 3]. Even though the aetiology and pathogenesis of the non-traumatic osteonecrosis are not fully understood it is associated with an array of systemic diseases and risk factors and frequently presents a multifocal distribution. It is commonly affecting the femoral head as a progressive pathology, usually in young adults in their third to the fifth decade of life [4]. In the majority of the cases (> 80%) it is bilateral and at late stages leads to collapse of the articular surface and gradual hip joint degeneration [5](Fig. 1). In the United States, more than 10,000 new patients are affected with the disease every year, and it accounts for up to 10% of total hip

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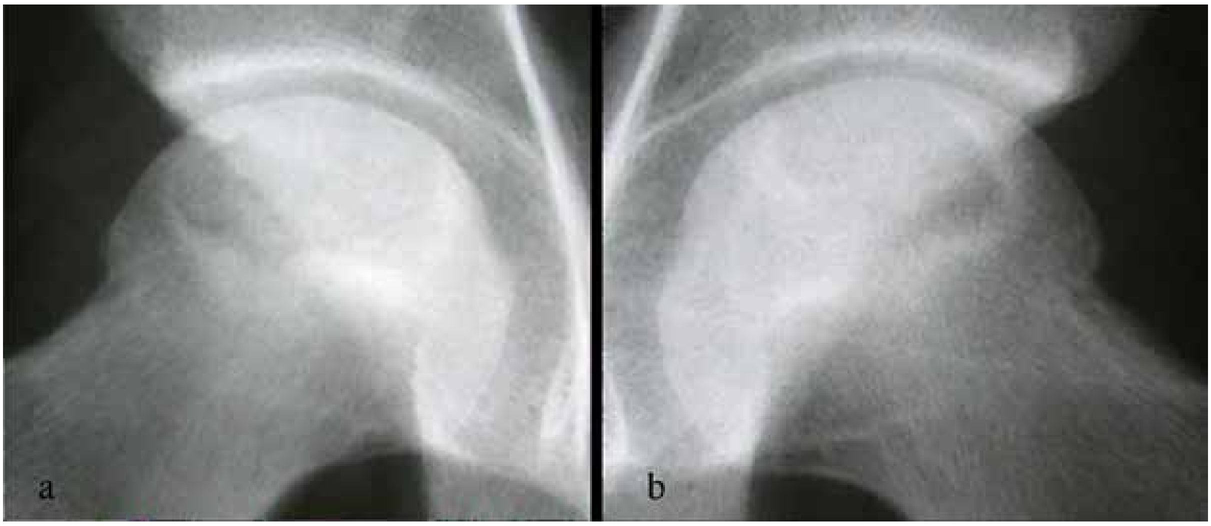

Figure 1. a & b: *Bilateral FHOn: Patient claimed for a vague groin pain on his right hip (a), reflecting to the medial aspect of the thigh and buttock. Careful clinical evaluation revealed restricted motion of the right hip joint and pain mainly elicited in flexion and internal rotation of both hips. Radiographic evaluation revealed bilateral FHOn.*

arthroplasties [4, 6, 7]. Early diagnosis and management aim to suspend the process of joint destruction through enhancement of bone repair and bone renewal.

A. Pathogenesis

Osteonecrosis of the FH may be related to:

i. Ischemia from a:

1) Direct blood vessel injury (after trauma such as fracture of the femoral neck, hip dislocation, fracture of the femoral head).

2) Intra-luminal obliteration of vascular supply from embolic matter such as clots, lipids, immune complexes, or sickle cells can also occlude the terminal arterioles in the subchondral bone.

3) Extra-luminal obliteration of the small vessels within the bone marrow. The common final mechanism is ischemia. The lack of collateral vessels at the sub-chondral zone of the weight bearing area, leads to the establishment of an infarct underneath the articular surface [8, 9, 10].

ii. Cellular toxicity

1) Pharmacologic agents (Corticosteroid use, non-steroidal chemotherapeutic agents for leukemia and other myelogenous diseases including tyrosine kinase inhibitors, monoclonal antibodies, mammalian target of rapamycin inhibitors, radiopharmaceuticals, selective estrogen receptor modulators and immunosuppressants)

2) Alcohol overuse

3) Irradiation

4) Oxidative stress [11, 12, 13, 14, 15, 16]

Overuse of glucocorticoids, and alcoholism are implicated in >80% of the cases and it is well established that the mechanism which causes blood vessel functional impairment in these cases does not have an embolic pattern and probably is characterized by genetic predisposition. A recent review article by Wang et al. listed five major theories about the pathogenesis of steroid induced ONFH referred to a. lipid metabolism disorders, b. decreased osteogenesis potential, c. insufficient blood supply, d. cell apoptosis, and e. gene polymorphism [17]. The ARCO (Association Research Circulation Osseous) has proposed classification criteria of corticosteroid-associated ONFH including: 1) history of corticosteroid use > 2 g of prednisolone or its equivalent within a 3-month period, 2) osteonecrosis should be diagnosed within 2 years after corticosteroid usage, and 3) patients should not have other risk factor(s) besides corticosteroids [18]. In this template as well, alcohol-associated ONFH is defined by the following conditions: 1) history of alcohol intake > 400 mL/week (320 g/week, any type of alcoholic bev-

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erage) of pure ethanol for more than 6 months, 2) ONFH diagnosed within 1 year after alcohol intake of this dose and 3) patients should not have other risk factor(s) than alcohol abuse [19].

iii. Genetic and epigenetic aetiologies regulating blood vessel tone, collagen production and the metabolism of steroids and alcohol such as mutations in the *COL2A1*, VEGF, eNOS (endothelial NO synthetase) and peroxisome proliferator activated receptor gamma (PPARG) genes, have been associated with the pathogenesis of osteonecrosis [20, 21, 22]. Moreover, significantly high prevalence of common thrombophilic states with genetic basis like the factor V Leiden mutation, the prothrombin gene G20210A mutation, antithrombin III deficiency, protein C and protein S deficiency and the methylene-tetrahydrofolate reductase (MTHFR) C677T gene polymorphism have been identified in patients with primary ONFH [23, 24]. Molecular techniques like genome-wide association study (GWAS), which identifies single nucleotide polymorphisms (SNPs) in the genome and establishes their relative association to a particular phenotype are going to enlighten us significantly in the future regarding the genetic basis of femoral head osteonecrosis pathology.

Pathogenesis: The underlying bone pathology is developed as the necrotic trabecular and the sub-chondral bone plate denuded from the proteins and the organic elements, upregulates tartrate-resistant acid phosphatase (TRAP)-positive osteoclasts, attracted by the local cytokines from the adjacent living bone, to gradually resorb the dead bone of the infarct. This inflammatory "repair tissue front" reaction is triggering osteoclastogenesis and scavenging with lysis of the dead trabeculae. This process is accompanied by new bone formation from the osteoblasts, but within the hypoxic environment the osteoblastic healing reaction is un-coupled early on, as the weakened trabeculae are fractured under the contact forces on the articular surface from weight bearing and repetitive loading. After collapse of the articular surface, the detached cartilage and the sub-chondral bone plate are dehisced and appear on the x-rays as a "crescent sign". This process is progressively expanding, and the collapsed infarct is sequestered and disintegrates, leading to secondary joint destruction [2, 25, 26].

TABLE 1.

Non-traumatic Osteonecrosis associated conditions	
Coagulation disorders	Hematologic diseases
Deficit of antithrombin III	Haemophilia
Deficit of protein C	Hemoglobinopathies
Deficit of protein S	Polycythaemia
Resistance to activated protein C	**Metabolic diseases**
Deficit of plasminogen activator	Hyperparathyroidism
Subplace of plasminogen activator inhibitor (PAI)	Gout
PAI 1 polymorphisms	Cushing disease
eNOS (endothelial NO synthetase) polymorphisms	Gaucher disease
Factor V mutation	**Exogenous risk factors**
Secondary conditions of hypercoagulation	Smoking
Intake of steroids, alcoholism	Decompression disease (divers- caisson disease)
Malignancy	Irradiation
Myelodysplastic syndromes	Haemodialysis
Pregnancy	Chemotherapy
Contraceptive use	
Hyperlipidaemia	
Collagen diseases	
Ehlers–Danlos syndrome	
Raynaud's disease	
Diabetes mellitus	
Antiphospholipidemic antibodies (APLA)	
Alimentary system diseases (Pancreatitis)	
Antiretroviral therapy for HIV	

B. Risk factors

ONFH may be associated with trauma (traumatic osteonecrosis) but in most cases it is non-traumatic.

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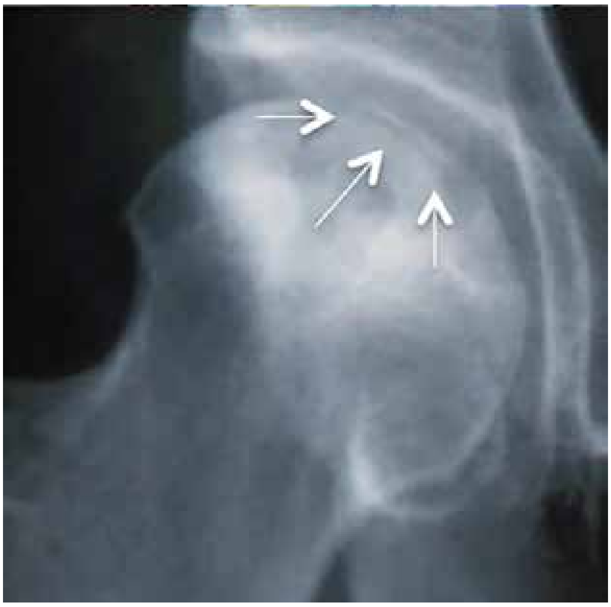

***Figure 2.** Radiographic image of a femoral head with osteonecrosis depicting the sub-chondral fracture "Crescent sign".*

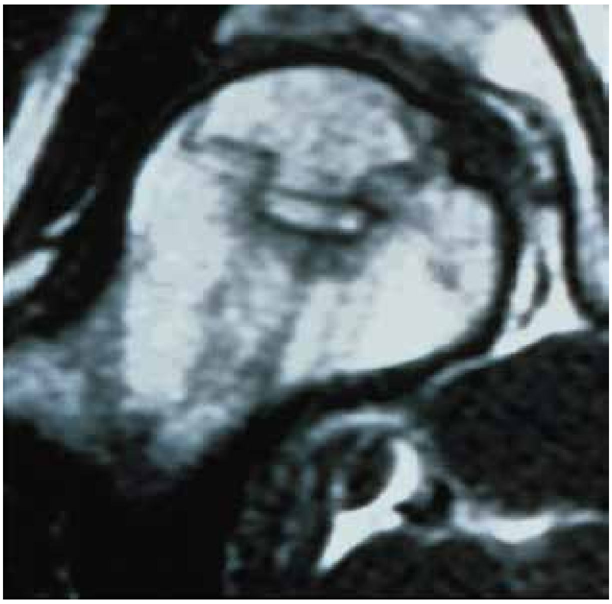

***Figure 3.** MRI for the diagnosis of FH ON*

Nontraumatic ONFH has traditionally been classified as idiopathic or secondary, depending on the absence or presence of known causes. Non- traumatic osteonecrosis may be associated with the use of high dose of corticosteroids in patients under chemotherapy and in auto-immune diseases, coagulopathies, special conditions causing secondary hyper-coagulate status, hematological and metabolic diseases, alimentary system diseases, while certain other risk factors such as smoking, overuse of alcohol, decompression disease, radiation and hemodialysis have also been correlated to the disease (Table 1). Not all patients exposed to a certain risk factor develop osteonecrosis of the femoral head, indicating that development of osteonecrosis is a complex, multifactorial, and not fully understood process involving both environmental influence and genetic predisposition. Steroids seems to be the major risk factor in acute lymphoblastic leukemia, chronic myeloid leukemia and acute myeloid lymphoma in which there is an increased risk of osteonecrosis [16, 27]. Osteonecrosis (ON) has been increasingly documented, particularly in pediatric ALL and well-known risk factors for this complication in this group of patients are the age above 10 years, female sex, use of dexamethasone (DEX), insufficient level of 25(OH)D, plasminogen activator inhibitor-1 (PAI- 1) and vitamin D receptor gene (VDR) polymorphisms [28, 29].

Use of corticosteroid-based therapy to reduce inflammatory-induced lung injury has been described for patients with severe COVID-19 like the use of corticosteroids to treat severe acute respiratory syndrome (SARS) during the SARS outbreak in 2003. However, improper use of systemic corticosteroids can increase the risk of osteonecrosis of the femoral head (ONFH) [30, 31, 32]. The otherwise limited modern literature suggests that corticosteroids should be considered only for patients undergoing septic shock, or in critical cases and in general should be minimized in dose and duration, and moreover the use of multiple types should be avoided [30, 32, 33]. Early screening, at three to four months after corticosteroids therapy, is suggested for COVID-19 patients.

C. Diagnosis:

The multifactorial etiologic profile of the disease requires a high degree of suspicion by the treating physicians (oncologists, haematologists, rheuma-

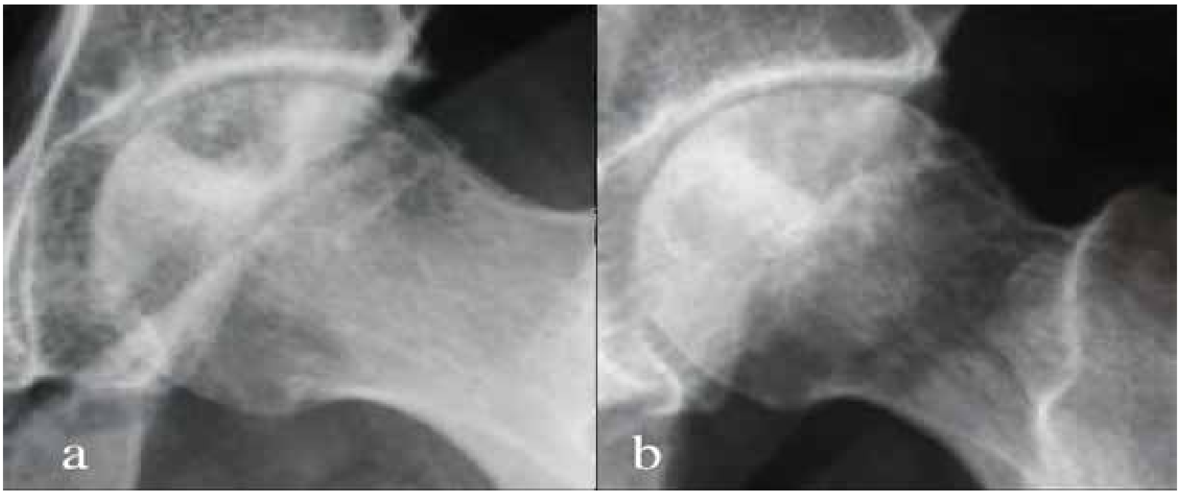

Figure 4. ***(a)*** *Small lesion involving less than 30% of the femoral head, may last for years before collapse.* ***(b)*** *More extended lesion involving >30% of the femoral head associated with higher collapse risk.*

tologists etc) in all patients with the predisposing risk factors, as the disease may remain quiescent for an unpredictable period of months after the infarct is established. It is advised to screen with an MRI of the hips every patient at risk of developing osteonecrosis, for the early detection of the disease which might lead to early management and possible hip joint-sparing.

ONFH presents an insidious onset with the patient complaining for a vague groin pain as the main symptom. In many cases it may be reflecting to the medial aspect of the thigh, the ipsilateral knee or buttock (Fig.1). The pain is relieved with rest. Careful clinical evaluation will reveal limited or restricted motion of the joint and pain mainly elicited in flexion and internal rotation of the hip. As the disease progresses so do the symptoms and in late stages, when collapse of the femoral head occurs, the patient is limping, and the hip joint deteriorates [34, 35].

D. Imaging:

Plain anteroposterior and frog-leg lateral radiographs have little to offer in early beginning of the disease, as they may appear completely normal. The initial findings include sclerosis surrounding a lucent area or segments with osteopenia within the femoral head. Radiographs are highly specific for more advanced osteonecrosis (Ficat II or III) and painful stages, the articular surface is fractured and a subchondral demarcation line is identified as the "crescent sign", but not very sensitive for early changes (Ficat I). In late stages gradual flattening of the articular surface and associated degenerative changes of the hip joint occur, which in large lesions, finally lead to progressive joint degeneration (Fig. 2) [34].

MRI is the most sensitive and specific diagnostic tool (99%), particularly helpful (for screening) in the very early stages, distinguishing premature necrotic lesions within the normal viable bone of the femoral head (Fig. 3). T1 images on MRI typically demonstrate a serpiginous "band-like" lesion with low signal intensity in the anterosuperior femoral head. A "double-line sign" can be seen on T2 sequences, which depicts a high signal intensity reparative interface of vascular reactive bone adjacent to necrotic subchondral bone. Bone marrow oedema around the necrotic lesion, may be present, mostly following a recent collapse and it is highly correlated with more hip pain [36, 37].

^{9m}Tc-methylene diphosphonate (MDP) bone scintigraphy, reflects osteoblastic activity and blood flow which are absent in osteonecrosis -"cold within hot" lesion at initial stages of asymptomatic disease. Its use is beneficial in detecting early stages of the disease and in diagnosing multifocal osteonecrosis of the skeleton. Irradiation in addition to poor specificity remain the main drawbacks of this exam, but it can be used to detect inflammatory activity in the femoral head when MRI is contraindicated. As more sensitive and specific, a whole-body MRI is preferable [35].

Computed tomography (CT) may be superior to MRI in detecting subchondral fractures and small areas of collapse which are suspected but not seen on plain films or MRI, but less sensitive than MRI in detecting osteonecrosis. On the other hand, the additional cost and radiation exposure are not justified [34, 38]. Recently, it has been proposed that nuclear medicine imaging technology such as SPECT/CT bone scan and 18F-fluoride PET/CT could demonstrate similar or better results in comparison to MRI in AVN of the femoral head and serve a complimentary role in equivocal cases [39].

E. Differential diagnosis:

FHON should be distinguished from Transient Bone Marrow Oedema (TBMO), a self-limiting condition presenting also with acute groin pain (occasionally throbbing) which involves women in their last months of pregnancy, or men on their 5th or 6th decade of life. Bone marrow oedema is also combined with transient osteoporosis, but subchondral lesions rarely exist. On rare occasion, reports have shown that bone marrow oedema syndrome (BMOS) may coexist with osteonecrosis. This finding has generated some controversy as to whether the two conditions coexist or if BMOS is a precursor to osteonecrosis. Other benign or malignant bone pathology of cartilaginous origin (chondroblastoma & clear cell chondrosarcomas) within the femoral head have rarely been reported. The lack of a serpentine line demarcating the infarct facilitates diagnosis [34, 35, 40].

F. Severity of ONFH

Aiming at the precise determination of the stage of the disease and therefore at the possibility of elementary prediction of its natural history and its treatment, more than 16 different staging systems have been proposed in the literature for evaluating ONFH, mainly based on the MRI and X-ray findings. The Arlet-Ficat (1960 and revised at 1985-commonly used), the ARCO (1991 and revised at 2019), the Japanese Orthopaedic Association (1987), the Pittsburgh classification (1984-Steinberg), the Kerboul (1974) staging systems combine findings both on plain radiographs and on the MRI as well as the proportion of the femoral head affected (Table 2).

Although all these classification systems lack high intra-observer and inter-observer reliability and validity can adequately differentiate the pre-collapse lesion which requires conservative treatment or minimal surgical approach [34, 41, 42, 43, 44]. Generally, if more than 30% of the femoral head is involved a greater risk (95%) for hip collapse within two years exist (Fig.4a &b).

G. Prognosis:

It depends on the location in relation to the weight bearing surfaces, the extent of the lesion, the presence of subchondral fracture and different morphologies of the necrotic-viable interface in osteonecrosis of the femoral head. The grater the extent of the infarct the worse the prognosis as more unfavourable outcome occurs (Fig. 4). Lesions extending beyond the lip of the acetabulum present the worst prognosis and major risk of future collapse. Recent or continuing collapse of the affected segment, together with aggravation of pain and extensive bone marrow oedema of the proximal femur are signs of rapid degenerative changes and deterioration of the hip joint function. Additionally, in a recent study by Kwon HM et al. has been proposed that a high pelvic incidence was associated with a greater likelihood of femoral head collapse in patients with nontraumatic ONFH. Clinical signs and symptoms correlated with the radiographic evaluation are necessary for the assessment of the severity and selection of the appropriate treatment [34, 45, 46, 47, 48].

H. Treatment options

I. Non-operative with partial weight bearing and activity modification, is indicated only in the early stages for very small lesions (<10%) and requires constant re-evaluation for the disease progression. However, it has no role in treatment of late-stage osteonecrosis and show limited success in preventing disease progression, even in early stages. Several additional measures to the nonsurgical treatment

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Figure 5. *Surgical treatment of FH ON with the implantation of vascularised fibula graft. (a) Preoperative radiograph. (b) and (c) Postoperative MRI and radiograph depicting the implanted fibula.*

have been suggested, such as shock wave therapy, pulsed electromagnetic fields, hyperbaric oxygen and pharmacological agents (anticoagulants, lipid-lowering factors, bisphosphonates**,** growth factors, antioxidants, and vasoactive substances) but there are not enough data in the literature to support their proven effect in preserving the hip joint. Patients are encouraged to abstain from or decrease alcohol consumption and smoking. [2, 9, 25]

II. Surgical management: except for the very small lesions where the natural history of the disease may last for years without an operation, larger lesions will eventually collapse and lead to joint replacement. In the early stages, prior to articular surface collapse, a variety of surgical procedures have been described for the preservation of the hip joint.

II.a. S**alvage procedures:** include core decompression after, various bone grafting technics and rotational osteotomies. Core decompression is carried out either with multiple drilling within the lesion with smooth pins (4-5 mm) drillings into the lesion, relieving intra-osseous pressure and inducing micro fractures to initiate a healing response. It is indicated for small sclerotic lesions in the early stages and its main drawback is the potential weakening of the adjacent intact cancellous bone [49, 50]. Efficacy has improved over the past 20 years, and this may be due to improved patient selection or the use of new surgical techniques such as multiple percutaneous drilling.

A variety of bone grafting techniques have been introduced combined with core decompression, to substitute the cored out necrotic bone, thus providing mechanical support and reconstituting the subchondral area with new bone-callus formation to prevent collapse. There are many studies since 2010 aimed to determine the effectiveness of bone marrow aspirate concentrate (BMAC), platelet-rich plasma (PRP), bone morphogenetic proteins (BMP) or their combination with CD in early stages of AVN hip, prior to collapse of femoral head [51, 52, 53, 54].

Implantation of one 11 mm or multiple 4 mm porous Tantalum rods is an alternative option, to provide mechanical support of the affected subchondral bone in carefully selected precollapse patients, but the results of many studies have not been optimal. Because of the increased complication rates in patients who undergo THA following tantalum rod failure, this treatment modality has fallen out of favour [2, 55]. The most advantageous grafting procedure is the implantation of a vascularised bone graft, as it combines the benefits of necrotic bone excision and core decompression with adequate mechanical support of the subchondral bone, together with the osteoinductive, osteoconductive and osteo-regenerative properties of an autologous bone graft, in addition to re-vascularisation of the affected area (Fig. 5). Autologous free vascularized fibula implantation has been proven very successful for intermediate size lesions prior to articular surface collapse [56, 57].

Figure 6. *Progressive joint degeneration in late stages of FHOn. (a): Preoperative radiographic appearance of femoral head advanced collapse due to On. (b): Pathologic appearance of the bisected, excised, femoral head.*

In addition, the vascularized iliac bone flap grafting technique yields significant improvement for restoration of the biomechanical support of the collapsed femoral head and reconstruction of the blood supply to the osteonecrotic area [58].

Nonvascularized fibular grafts, cortical strut grafts, or cancellous bone chips are viable options for the treatment of ONFH. Techniques for the implantation of these grafts include the Phemister technique, the trapdoor, and the lightbulb technique [2, 29]. Intertrochanteric or rotational osteotomies of the proximal part of the femur for the transposition of the effected segment away from the weight bearing area, also consist a hip salvage procedure. The long-term results, however, remain controversial [59, 60].

II.b. Hip replacement procedures: although non desirable in the younger ages, in late stages or in elderly patients with established degenerative changes of the hip, joint replacement surgery is the treatment of choice (Fig. 6). Total hip arthroplasty provides pain relief and early functional improvement but durability of the prosthesis is the main drawback as osteonecrosis affects mainly young energetic patients in their productive life years. The long-term survivorship of the THA is comparable to that for osteoarthritis in general, except for the cases with haemoglobinopathies, renal failure in dialysis and autoimmune diseases, which may present higher rates of early failure, and infections. Hip resurfacing arthroplasty is another option, but it has not been proven equally successful to THA [61, 62, 63].

I. Take home message

Osteonecrosis is a pathology commonly seen in younger adults, in which collapse of the femoral head and early onset of joint degeneration may eventually necessitate hip arthroplasty when non-operative measures and joint-sparing procedures fail. Patients on chemotherapy or with auto-immune diseases receiving high dose steroids are considered at risk, for the functionally debilitating ONFH, and an MRI of the hips is recommended for screening and early-stage detection. The same is valid for those with two or more aetiology associated risk factors. Higher age, higher BMI, and higher stages with large lesions of osteonecrosis are determinants of likelihood of conversion of joint-sparing procedures to THA. These factors can be useful during patient selection for joint-sparing procedures.

Conflict of interest disclosure:
The authors declared no conflicts of interest.

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Stefanou N, Koutalos AA, Papanagiotou M, Malizos KN. Current trends and controversies in femoral head osteonecrosis. *Acta Orthop Trauma Hell* 2022; 73(1): 33-44.

Short femoral stems with metaphyseal or meta-diaphyseal fitting in total hip arthroplasty: a systematic review

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ABSTRACT

Background: Great variety of short stem designs have been introduced in the market in order to find the ideal combination of bone and soft tissue preservation, optimal stress distribution, excellent functional outcome and survival rates.

Purpose: Summarize and analyze the published data, in terms of clinical and radiological outcomes, complications, revision rates, and implant survival, on tapered-wedge short femoral stems which have metaphyseal only or metaphyseal-proximally diaphyseal fixation and require conventional neck osteotomy.

Methods: Review of literature databases, using the MEDLINE, Embase, and Web of Science, was conducted based on strict inclusion and exclusion criteria to identify studies reporting clinical and radiological outcomes for this specific type of short femoral stems.

Results: Thirty-six studies involving 3535 patients (3786 hips) with a mean age of 61.3 (27.5-74.42) years in a mean follow up of 45.54 (12-120) months were included. Mean Harris Hip Score improved from 45.72 (27.29-60) to 91.44 (83.1–100). The mean University of California at Los Angeles activity level and mean Merle d'Aubigné functional score was improved from 3.71 (3-3.9) to 6.06 (4.7-7.5) and 10.4 (8.5–11.5) to 17.29 (15.5–17.8) points, respectively. Femoral stem was implanted in neutral coronal alignment in 63.6% hips. A total of 30 studies reported revision rate, which was 0.03% (0-17%) and 12 studies presented component survivorship, which was 99% (96-100%) in average of 5.5 years.

Conclusions: Short, tapered-wedge stems with metaphyseal or meta-diaphyseal fitting demonstrate similar excellent clinical outcomes, survivorship and revision rates with low incidence of complications, as the conventional length or other types of short femoral components. Some concerns regarding the incidence of stress shielding phenomenon and coronal stem malalignment have been raised, requiring further evaluation through long-term studies.

KEYWORDS: Total Hip Arthroplasty; Short Femoral Stems; Metaphyseal Fitting

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Introduction

An increased rate of 8% in cementless short stem total conventional hip arthroplasty (THA) has been recorded by Australian registry in 2019 (1). Short stems have been designed with the theoretical advantages of accommodating less invasive surgical techniques, sparing bone and soft tissue, optimizing stress distribution at the proximal femur, minimizing stress shielding effect, reducing the incidence of thigh pain, and simplifying future revisions (2,3). Studies have demonstrated that short stems load better the proximal metaphysis and improve proximal implant fixation, reproducing a biomechanical behavior more similar to the physiological bone, hence, they provide higher osseointegration rates minimizing stress-mediated bone resorption (4,5).

Although the risk of aseptic loosening and intraoperative fractures using short stems is better or comparable to conventional stems, high rates of revision are still reported due to primary instability and pain (4,6). The 15-year cumulative percent of revision for primary THA using short stems was 6.3% compared to 7.8% for conventional femoral stems, in 2020 (1). However, because of the great variability of short stems in terms of design, biomechanics, and principles of fixation, the clinical results should be interpreted with great criticism. In the last decade, tapered-wedge short stems with meta-diaphyseal fixation have been introduced in the market and they have become more popular, aiming to maintain the advantages of short femoral protheses, but additionally to reduce micro-rotation due to meta-diaphyseal fitting (7–9).

There are many classifications of short stems described in the literature. Khanuja et. al. (10) defined a classification system of short stems based on fixation principles and location of proximal loading, with the following categories: femoral neck only, calcar loading, lateral flare calcar loading, and shortened tapered. Feyen et. al. (11) classified the short stems in five categories according to the required level of femoral neck osteotomy and the intended site of primary stability. McTighe et al. (12) advocated a classification system by primary stabilization contact regions, which consists of head stabilized, neck stabilized, metaphyseal stabilized, and conventional metaphyseal/diaphyseal stabilized. Falez et. al. (13) classified short stems based on the level of femoral resection and proposed 5 categories: collum, partial collum with neck preserving osteotomy, trochanter sparing and trochanter harming. Summarizing existing classification systems and accounting for all short stem characteristics, Ǵomez-Garćia et al. (14) presented a nomenclature-coding system. Tournier et. al. (15) proposed a 5-fold classification based on the anchorage zone inside the femur for the French Hip & Knee Society (SFHG).

The purpose of this systematic review is to summarize and critically analyze the published literature focused on short femoral stems which are tapered wedge design (type-4 by Khanuja et. al. (12)), require conventional osteotomy, and have metaphyseal only or metaphyseal-proximally diaphyseal fixation (type IVB by Feyen et. al. (13) and either class 3 or 4 by McTighe et. al. (14)). We particularly aim to assess short stems with these specific characteristics in terms of clinical and radiological outcomes, complications, revision rates, and implant survival.

Methods

This systematic review was designed and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (16).

A comprehensive electronic search of MEDLINE, Embase, and Web of Science from the earliest available year of indexing until October 2021 was conducted. We screened databases by using the following keywords and their combinations: short stem, conventional osteotomy, tapered-wedge design, new generation, meta-diaphyseal fixation, metaphysis and diaphysis fixation, Tri-Lock BPS (Tri-Lock Bone Preservation Stem), Taperloc, Taperloc Microplasty, Accolade II, Accolade 2, Centpillar TMZH, Centpillar GB, Centpillar, MINIMA S, MINIMA Lima, Optimys, Optimys Robert Mathys, Fitmore, Exacta, Exacta S, GTS stem, GTS Biomet, CLS Brevius, CLS stem, AJS Implantcast, Balance Biomet, Balance Microplasty, Symbios SPS, Symbios. Following the electronic search, we carried out supplementary manual research of the reference lists of all retrieved articles to identify potential eligible

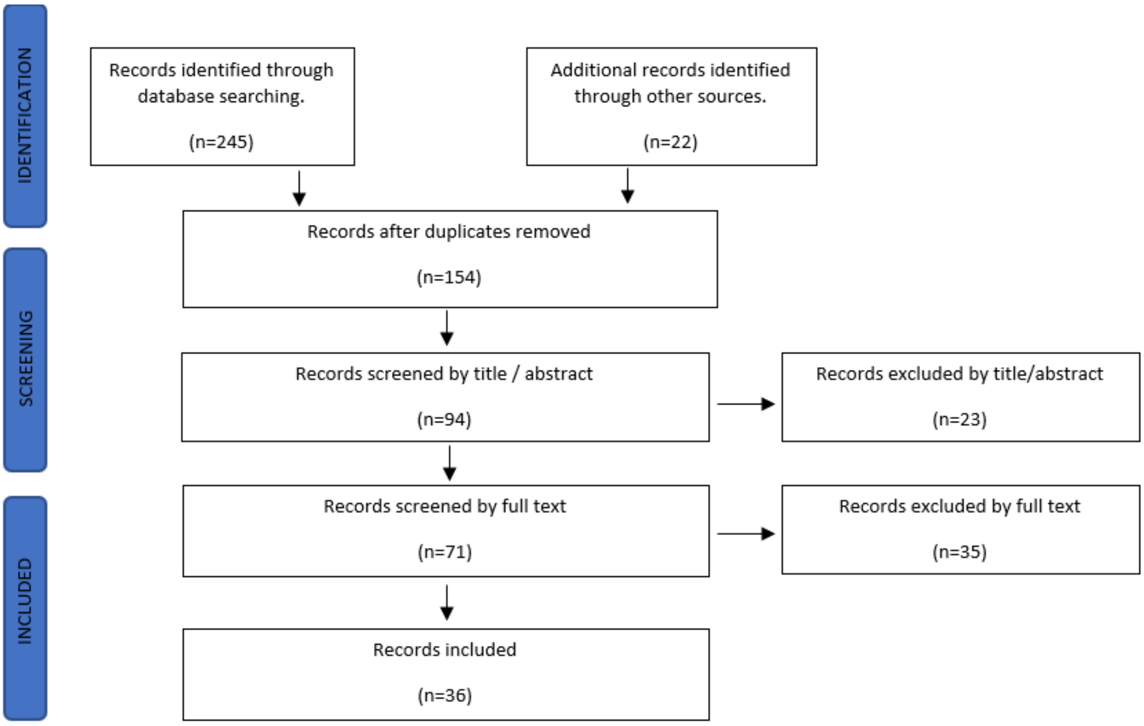

Figure 1

studies. Abstracts of all citations were screened, and full texts of articles were assessed to decide on inclusion of relevant studies. The attrition flowchart is shown in Figure 1.

The authors independently review the articles, extracting data relating to the design of the study, the period of study, case selection, the assessment of outcome, the demographic characteristics of the patients, the follow up, and femoral prothesis type. The inclusion criteria for this systematic review were as follows: (I) reporting THA with a short, tapered-wedge, meta-diaphyseal fitting stem, which required conventional osteotomy; (II) retrospective or prospective studies including randomized controlled trials, non-randomized trials, cohort studies, case–control studies, and case series studies; (III) comparative studies of femoral stems, which provide clear separation of data; (IV) at least one functional assessment score; (V) a minimum of 24 months follow up; (VI) the language of the publications was limited to English. The exclusion criteria were as follows: (I) comparative studies of stems without clear separation of data; (II) comparative studies with subgroups of the same prothesis; (III) nonhuman subjects; (IV) revision surgery; (V) papers not related to the research item. All relevant studies were assessed according to their Levels of Evidence (LOE) based on the 2011 Oxford Centre for Evidence-based Medicine(17). Data were expressed with mean ± standard deviations (SD) and range of minimum and maximum for continuous variables and with number of cases or percentage for categorical variables.

Results

A total of 36 studies were identified, following the research protocol, between 2014 and 2021. There were 5 randomized control trials (LoE I), 9 prospective cohort studies (LoE II), 1 prospective comparative study (LoE II), 7 retrospective cohort studies (LoE III), 4 retrospective comparative studies (LoE III), 5 prospective observational studies of case series (LoE IV), 5 retrospective observational studies of case series (LoE IV). A total of 3786 stems, used

TABLE 1.

Patients' Demographic data

STUDY	Stem type	LoE	No Hips	No Patients	Males	Females	Mean age (years)	Mean body mass index (kg/m2)	Dorr A/B/C	Duration of follow-up (months)
(Hayashi *et al.*, 2016)	Trilock BPS	II	65	65	11	54	65.1±10.4	23.4±3.5	3/58/4	24
(Hayashi *et al.*, 2017)	Trilock BPS	II	44	44	22	22	65.0±10.3	23.8±3.8	N/A	24
(Hayashi et al., 2020)	Trilock BPS	III	222	222	36	186	65.3±10.1	23.9±3.9	N/A	63.6
(Zhen *et al.*, 2021)	Trilock BPS	IV	42	35	27	8	27.5±3.7	20.2 (16.8–23.2)	0/0/42	66±13.2
(Ulivi *et al.*, 2017)	Trilock BPS	III	163	163	59	104	74.42 (44-90)	26.88 (16.4-38.1)	39/116/8	84
(Albers *et al.*, 2015)	Trilock BPS	II	123	119	55	64	64.6 (34-89)	N/A	97/26/0	60 (49.2-66)
(Slullitel *et al.*, 2020)	Trilock BPS	I	46	46	22	24	60.4±10.1	27.4±2.9	N/A	48
(Amendola *et al.*, 2017)	Trilock BPS	II	238	238	104	134	64 (21–91)	30 (16–56)	N/A	36 (24-60)
(Tatani *et al.*, 2020)	Trilock BPS	I	45	45	16	29	63.89±8.56	28.45±4.95	12/28/5	48
	Minima S		45	45	23	22	63.49±8.16	28.52±4.31	14/24/7	48
(Guo *et al.*, 2021)	Trilock BPS	III	104	84	35	49	53.12±2.32	25.16±2.20	53/18/13	48.23±2.91
(Peng et al., 2021)	Trilock BPS	IV	55	55	42	13	49.8 (25–73)	23.8 (17.9–33.8)	10/43/2	42.5 (36–48)
(Schilcher et al., 2017)	Taperloc Microplasty	I	30	30	17	13	60.6±4.7	26.3±3.9	21/9/0	48
(Saragaglia et al., 2020)	Taperloc Microplasty	III	119	119	81	38	58.8±11	27.9±5.2	57/62/0	61±8
(Nahas et al., 2018)	Taperloc Microplasty	IV	196	196	105	91	59 (21–78)	N/A	N/A	36 (5 -75)
(Molli et al., 2012)	Taperloc Microplasty	III	269	246	111	135	63 (27–91)	30.1 (19–60)	N/A	29.2 (0.8-62.2)
(Gallart et al., 2019)	Taperloc Microplasty	III	40	32	20	12	50 (28-66)	27 (16.0–33.0)	12/19/9	36.5 (26 - 68)
(Lombardi et al., 2021)	Taperloc Microplasty	IV	92	92	41	51	63.2±10.1	30.8±6.8	N/A	54 (24-72)
(Hayama et al., 2020)	Taperloc Microplasty	III	257	235	34	201	63 (41–86)	N/A	N/A	53 (24-83)
(Uçan et al., 2021)	Taperloc Microplasty	I	40	20	8	12	52±14.1	24.9±3.2	N/A	28.7±3.8
(Pogliacomi et al., 2020)	Taperloc Microplasty	II	60	60	24	36	68.4 (58–83)	27.5 (23–31)	N/A	60
(Uemura et al., 2021)	CentPillar GB	III	198	181	11	170	56 (18–91)	22.9 (13.6–35.5)	131/88/3	13.1
	CentPillar TMZF		24							
(Nam et al., 2019)	Accolade II	II	31	31	24	7	52.6±6.5	27.9±3.9	N/A	24
(Sariali et al., 2017)	Symbios SPS	II	154	154	97	57	58.8±13.5	26.5±4.4	N/A	60
(Tostain et al., 2019)	Symbios SPS	IV	61	61	16	45	74 (44–83)	30.5	N/A	120
(Graceffa, 2016)	CLS Brevius	III	170	155	75	80	61.8 (42-67)	N/A	N/A	32 (24-44)
(Drosos et al., 2020)	Minima S	III	61	61	19	42	56±11.1	31.2±4.9	11/48/2	33.4 (12-57)
(Morales De Cano et al., 2014)	GTS Biomet	IV	81	80	55	25	64.8 (43–78)	N/A	N/A	16 (6-24)
(Thalmann et al., 2019)	Fitmore	II	96	96	58	38	62.32±9.97	N/A	79/17/0	60
(Acklin et al., 2016)	Fitmore	II	28	28	19	9	64 (22–75)	26 (19–36)	N/A	24
(Maier et al., 2015)	Fitmore	IV	100	100	55	45	59 (19–79)	N/A	N/A	39.6 (24-52.8)
(Freitag et al., 2016)	Fitmore	I	57	57	36	21	56.8±10.2	29.7±4.8	N/A	12
(Hochreiter et al., 2020)	Optimys	IV	46	46	21	25	65.7±9.3	N/A	N/A	24.1
(Djebara et al., 2021)	Optimys	III	47	47	22	25	66.8±6.4	26±3.2	N/A	12
(Kutzner et al., 2019)	Optimys	IV	201	162	89	73	63.5 (3.4–88)	N/A	N/A	61.7 (57.2–83.7)
de Waard et al., 2021)	Optimys	II	34	34	13	21	60	27	N/A	24
(Donner et al., 2019)	Optimys	IV	102	51	29	22	63.1 (36.7-76.8)	27.6 (19.6-41.8)	N/A	62.4 (57.6-75.6)

LoE – Level of Evidence

for primary THA, were included for analysis. The mean follow-up was 45.54 months, ranged between 12 and 120 months.

Tri-Lock Bone Preservation stem was used in 1147 primary THAs, in 11 studies and Taperloc Microplasty (Microtaperloc; Biomet, Inc, Warsaw, IN, USA) was used in 1103 hips, in 9 studies. 281 primary THAs with Fitmore stem (Zimmer Biomet, Winterthur, Switzerland), in 4 studies, were recorded and 430 hips received Optimys (optimys, Mathys Ltd., Bettlach, Switzerland), in 5 studies. Accolade II (ACCOLADE II, Stryker Orthopaedics, Mahwah, NJ, USA), Symbios SPS (SPS-Modular®; Symbios, Yverdon-les-Bains, Switzerland) and GTS (Biomet) were implanted in 31, 215 and 81 hips, respectively. 170 CLS Brevius (Zimmer GmbH, Winterthur, Switzerland), 106 Minima S stems (Lima Corporate, Udine, Italy), 222 CentPillar stems (CentPillar-GB and CentPillar-TMZF, Stryker Orthopaedics) have been recorded in primary THAs.

Demographic data. A total of 3786 hips and 3535 patients were reported in 36 studies. Mean age was 61.3, fluctuated between 27.5 and 74.42 years old. There were 1532 men and 2003 women. Information about mean body mass was available for 2346 patients, with a mean value of 27.1 kg/m2, ranged between 20.2 and 31.2 (kg/m^2). Dorr femoral bone classification was reported in 14 studies, 45.3% of femurs were type A, 46.7% were type B and 7.9% type C. Demographic data are presented on Table 1.

Clinical Outcomes. Harris Hip Score (HHS) at the final follow up was demonstrated in 28 studies. The mean Harris Hip Score (HHS) preoperatively was 45.72 (27.29 - 60), improving at follow-up to 91.44 (83.1 – 100) points. The mean HHS difference was 45.54 (32.3 - 69.9) points. Mean UCLA activity was reported in 8 studies and ranged between 3.71 (3 - 3.9) preoperatively and 6.06 (4.7 - 7.5) points at the last follow up. Merle d'Aubigné functional score was used in 4 studies with a mean value 10.4 (8.5 – 11.5) and 17.29 (15.5 – 17.8) points preoperatively and at the last follow up, respectively. Two studies reported a mean value of 48.17 and 92.31 points preoperatively and at the last follow up, respectively, based on the Japanese Orthopedic Association Score (JOA-S). Lastly, de Waard et. al. (18) described function by using Hip Disability and Osteoarthritis Outcome Score (HOOS) and reported a mean value of 27 preoperatively, improving to 87 postoperatively. All reported functional outcomes are demonstrated on table 2.

Regarding pain, Pain Visual Analogue Scale (VAS) was reported in 9 studies with mean values fluctuating between 6.45 (4.5-9.25) and 1.9 (0.1-5.9) preoperatively and at last follow up, respectively. Thigh pain was recorded in 23 studies, with a mean incidence of 6.02%, ranged between 0.51-20.1%. However, only in 4 studies, thigh pain classified as mild, moderate and severe in 19.4%, 7.9%, 2.6%, respectively for a total of 528 hips. Lastly, it has been demonstrated by Graceffa et. al. (19) that no patients reported thigh pain after primary THA with CLS Brevius, but 7% (12 patients) presented with severe trochanteric bursitis at one-year follow-up, which resolved in all but 3 cases till the last follow up.

Implant survival. Regarding survival rates of tapered-wedge short meta-diaphyseal fitting stems, which require conventional osteotomy, twelve studies reported survivorship rates at final follow-up. Overall combined component survivorship for these studies was 99% (96-100%) in average of 66.3 months for 1636 short stems (Table 3).

Revision Rate. In 30 of 36 reviewed studies, revision surgeries and complications have been described and presented on Table 3. The mean revision rate was 0.03%, fluctuated between 0% and 10.7%. The most frequent cause of revision was deep infection or sepsis reported in 7 (0.2%), followed by recurrent dislocation in 4 (0.12%) and periprosthetic fractures in 4 (0.12%). Least frequent causes of revision were aseptic loosening in 3 (0.09%), severe or unidentified thigh pain in 2 (0.06%), and major subsidence in 2 (0.06%). In 774 primary THAs using Tri-Lock BPS, 2 (0.25%) recurrent dislocations, 1 (0.13%) aseptic loosening, 1 (0.13%) infection, one case of 5mm subsidence (0.13%) and one case of severe thigh pain (0.13%) were recorded as causes of revision. Of 1103 primary THAs with Taperloc Microplasty, 5 (0.45%) cases were revised due to periprosthetic fractures (0.18%), recurrent dislocation (0.09%), deep infection (0.09%), and sepsis (0.09%).

Regarding most frequent complications, dislocation was noted at 0.57%, deep infection at 0.39%, deep venous thrombosis at 0.3%, intraoperative femoral fracture at 0.24%, severe thigh pain at 0.21%, and periprosthetic femoral fracture at 0.12%.

Radiological outcome. Femoral stem alignment recorded in 12 studies, nine out of them reported a neutral coronal alignment in 63.6% hips (range 1.2%-96%). Femoral components were placed varus in 14% (1.8%-60%) and valgus in 22% (1.8%-67.5%), respectively (Table 4). The mean alignment deviations from the neutral axis ranged between -1.4° to 1.99°. Thirteen studies assessed the incidence of stress shielding phenomenon in 1695 hips; it was

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TABLE 2.

Clinical outcomes in the reviewed studies

STUDY	Stem Type	No (hips)	HHS PRE	HHS POST	UCLA pre	UCLA post	Merle pre	Merle post	OHS pre	OHS post	JOA pre	JOA post	HOOS pre	HOOS post	WOMAC pre	WOMAC post
(Hayashi *et al.*, 2016)	Trilock BPS	65	N/A	90.4±8.6	N/A	5.9±1.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Hayashi *et al.*, 2017)	Trilock BPS	44	N/A	89.4±9.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Hayashi et al., 2020)	Trilock BPS	222	N/A	90.1±6.1	N/A	6.4±1.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Zhen *et al.*, 2021)	Trilock BPS	42	48.0±8.0	87.0±9.0	3.0±0.5	7.5±0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Ulivi *et al.*, 2017)	Trilock BPS	163	27.29±4.612	97.28±9.044			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Albers *et al.*, 2015)	Trilock BPS	123	41.9±15.2	84.5±12.6	3.9±2.1	5.8±2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Slullitel *et al.*, 2020)	Trilock BPS	46	PAIN (17.5±7.19) FUNCTION (27.7±7.64)	PAIN (35.6±8.43) FUNCTION (42.0±5.77)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	PAIN (47.3±17.7) STIFFNESS (43.8±20.7) FUNCTION (47.0±17.1)	PAIN (87.2±16.2) STIFFNESS (78.5±21.5) FUNCTION (87.2±14.4)
(Amendola *et al.*, 2017)	Trilock BPS	238	46±16	88±13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Tatani *et al.*, 2020)	Trilock BPS	45	46.63 (11.2)	95.38 (2.98)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66.42±13.4	8.2±3.13
	lima	45	48.8 (12.35)	96.03 (3.56)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66.36±15.71	7.49±3.23
(Guo *et al.*, 2021)	Trilock BPS	104	45.32±3.42	93.33±4.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	54.04±10.2	5.58±2.32
(Peng et al., 2021)	Trilock BPS	55	48.13±9.66	96.84±5.60	N/A	N/A	N/A	N/A	36.15±8.80	15.33±3.12	N/A	N/A	N/A	N/A	50.04±9.40	3.27±3.36
(Schilcher et al., 2017)	Taperlock Microplasty	30	52 (31-65)	100 (56-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34 (0-69)	94 (47-100)
(Saragaglia and Orfeuvre, 2020)	Taperloc Microplasty	119	N/A	N/A	N/A	N/A	11±2.3	17.8±0.8	42.5±7	13.1±3.5	N/A	N/A	N/A	N/A	N/A	N/A
(Nahas et al., 2018)	Taperloc Microplasty	196	N/A	N/A	N/A	N/A	N/A	N/A	21	45	N/A	N/A	N/A	N/A	N/A	N/A
(Molli et al., 2012)	Taperloc Microplasty	269	49.9	83.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Gallart et al., 2019)	Taperloc Microplasty	40	N/A	N/A	N/A	N/A	11.5 (11.1–12.8)	17.5 (17.2–17.9)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Lombardi et al., 2021)	Taperloc Microplasty	92	52.5	84.8	N/A	5.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Hayama et al., 2020)	Taperloc Microplasty	257	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	49	89	N/A	N/A	N/A	N/A
(Uçan et al., 2021)	Taperloc Microplasty	40	32.8±8.5	88.9±7.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	30.2 (19–41)	83.4 (76–90)	N/A	N/A	N/A	N/A	16.4 (12–28)	44.3 (37–46)	N/A	N/A	N/A	N/A	61.1 (52–84)	10.5 (8–15)
(Uemura et al., 2021)	CentPillar GB	198	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	47	97	N/A	N/A	N/A	7.6
	CentPillar TMZF	24														
(Nam et al., 2019)	Accolade II	31	53.3+16.8	86.4±20.8	N/A	7.3±1.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Sariali et al.,2017)	Symbios SPS	154	N/A	97±7	N/A	N/A	N/A	N/A	N/A	57±6	N/A	N/A	N/A	N/A	N/A	N/A
(Tostain et al., 2019)	Symbios SPS	61	43 [35–50]	91 (77–96)	N/A	N/A	8.5 (7–10)	15.5 (14-16.5)	N/A	17.2	N/A	N/A	N/A	N/A	N/A	N/A
(Graceffa et al., 2016)	CLS Brevius	170	32 (9-58)	92 (75-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Drosos et al., 2020)	Minima S	61	58.7±13.5	95.1±4.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Morales De Cano et al., 2014)	GTS Biomet	81	N/A	N/A	N/A	N/A	10 (8–14)	17.4 (12-18)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Thalmann et al., 2019)	Fitmore	96	59.2±15.6	93.8±10.25	N/A	N/A	N/A	N/A	N/A	41.02 (9.07)	N/A	N/A	N/A	N/A	N/A	N/A
(Acklin et al., 2016)	Fitmore	28	60 (30–80)	99 (83–100)	N/A	N/A	N/A	N/A	23 (10–37)	46 (42–48)	N/A	N/A	N/A	N/A	N/A	N/A
(Maier et al., 2015)	Fitmore	100	56 (14 -80)	94 (62 -100)	3.7(2–7)	6.7 (2–10)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	93 (58.3–100)
(Freitag et al., 2016)	Fitmore	57	52±13	85±14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.6±2.6	1.7±2.2
(Hochreiter et al., 2020)	Optimys	46	57.2±20	97.2±4.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
(Djebara et al., 2021)	Optimys	47	58.7±4.8	95.2±2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Kutzner et al., 2019)	Optimys	201	45.6 (7-88)	97.8 (65-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A
de Waard et al., 2021)	Optimys	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27 (17-40)	87 (74-94)	N/A	N/A
(Donner et al., 2019)	Optimys	102	44.2±15.2	97.8±5.3	3.8±2.0	4.7 (2.0-10)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	98.0 ± 5.8	N/A

HHS – Harris Hip Score, PRE – Preoperative, POST – postoperative, UCLA – University of California at Los Angeles activity level, Merle – Merle d'Aubigné functional score, OHS – Oxford Hip Score, JOA- Japanese Orthopedic Association Score, HOOS – Hip Disability and Osteoarthritis Outcome Score, WOMAC – Western Ontario and McMaster Universities Arthritis Index.

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grade 1 in 56.6% hips, affecting mostly Gruen zones 1 and 7. Grade 2 was noted in 12.7% hips, while grade 3 in 0.47%. Only one hip (0.059%) implanted with the CentPillar stem showed grade 4 stress shielding effect at last follow up (20) (Table 5). In 8 studies, all femoral components were considered osseointegrated, and only in one study the osseointegration rate was 96.4% (21). The incidence of heterotopic ossification ranged between 0 and 19%, according to 10 of the reviewed studies. From sixteen studies reported on the incidence of radiolucent lines, only 9 studies noted the presence of radiolucent lines under 1 mm in 17% hips (range 0.61%-45.5%). Two studies demonstrated calcar osteolysis, in 5% and 75% hips implanted with the Symbios SPS (22) and Fitmore (23) femoral stems, respectively. The mean incidence of aseptic loosening at the last follow up in a total of 1263 hips within 11 studies was 0.02%. Subsidence of femoral component noted by 20 authors with a mean value of 0.36 mm (0 - 1.93 mm). In 6 cases, a major subsidence (>2 mm) was noted, and the femoral component had to be revised in two of them. Each radiological parameter described in the included studies is shown in Table 5.

Discussion

Our study systematically reviewed and assessed all available studies presenting the clinical and radiological outcomes, survival rates, revisions and complications of several short femoral components with metaphyseal or meta-diaphyseal fixation that require conventional neck osteotomy. Since most of the currently available short stems of this category are relatively new with short term clinical performance, clinical evidence with more than 24 months follow up was limited to a small number of studies. Therefore, it was not surprising that studies on some brands have not been included in this review.

As THA has expanded its indications and is being performed in younger and more active patients, the need for an optimized femoral prothesis for bone and soft tissue preservation is of utmost importance. A growing interest towards short versions of uncemented femoral implants is recorded in the current literature as an effort to address this issue. The fact is that a heterogeneous group of short femoral prostheses with differences in operative technique, design philosophy and method of fixation has emerged in clinical practice, and long-term data are still awaited. In this systematic review, we concentrated on short stems with metaphyseal only or metaphyseal-proximally diaphyseal fitting and conventional neck osteotomy, which gain popularity in the market according to registries. Furthermore, most orthopaedic surgeons are familiar with the implantation process required for this type of prostheses that presents similarities to that of a conventional stem. In the UK during 2020, Accolade II was used in 13% of primary THAs, moreover an increased trend in the use of Taperloc Microplasty, Tri-Lock BPS, Symbios SPS has been observed (25). The use of Accolade II and Taperloc Microplasty has been increased the last five years in Australia (1) and an increasing trend is also observed in National Joint Registry data (25). According to the Swiss Registry, an increased trend in the use of Fitmore, Optimys and Tri-Lock BPS femoral stems was noticed (26).

According to a previous systematic review on short metaphyseal loading cementless stems, similar improvement in clinical and radiological outcomes was noted compared to conventional length implants (24). However, coronal stem malalignment, stress shielding effect, cortical hypertrophy or implant's subsidence as well as their consequence of fracture risk and aseptic loosening still remain a concern with certain short stem designs (5).

In this systematic review, a total of 3786 hips in 3535 patients were analyzed. The mean age of patients was 61.3 (27.5-74.42) years old. Two third of the included studies reported a mean age above 60 years old, with two out of them reported cohorts with a mean age of 74 years old, which is higher than the reported average between conventional short stems (5,24). Only Zhen et al. studied young adult osteoporotic patients with mean age of 27.5 years old, who had Dorr type C femur, investigating the wide spectrum of Tri-Lock BPS prothesis. On the contrary, the majority of included studies reported high incidence of Dorr type A and B femurs, 45.3% and 46.7%, respectively, and only 7.9% type C (3,27). Patients with Dorr type C femur are more

TABLE 3.

Component Survivorship, Revision and Complication rates

Study	Stem Type	No Hips	Survival Rate	Revision	Reason for revision	Complications
(Ulivi *et al.*, 2017)	Trilock BPS	163	99%	1(0.61%)	1 recurrent dislocation	1 dislocation
(Albers *et al.*, 2015)	Trilock BPS	123	99.2%	1 (0.81%)	1 >5mm subsidence	2 Intraoperative great trochanter fractures 2 dislocations 1 subsidence
(Slullitel *et al.*, 2020)	Trilock BPS	46	N/A	1 (2.17)	1 aseptic loosening	1 calcar crack 1 femoral nerve palsy 5 thigh pain 1 aseptic loosening
(Amendola *et al.*, 2017)	Trilock BPS	238	N/A	2 (0.8%)	1 infection 1 tight pain	2 infections 2 heteropic ossification 1 tight pain
(Tatani *et al.*, 2020)	Trilock BPS	45	N/A	0		2 superficial infections
	Minima S	45	N/A	0		1 superficial infection
(Guo *et al.*, 2021)	Trilock BPS	104	98.80%	1 (0.96%)	1 recurrent dislocation	1 dislocation 3 pneumonias 2 limp nerve numbness 1 intraoperative periprosthetic femoral fracture
(Peng et al., 2021)	Trilock BPS	55	100%	0		0
(Schilcher et al., 2017)	Taperloc Microplasty	30		0		0
(Saragaglia et al., 2020)	Taperloc Microplasty	119	100%	1 (0.84%)	1 recurrent dislocation	2 deep venous thrombosis 1 pulmonary embolism 3 dislocations
(Nahas et al., 2018)	Taperloc Microplasty	196	N/A	1 (0.5%)	1 periprosthetic fracture	3 dislocations 1 subsidence 1 periprosthetic fracture
(Molli et al., 2012)	Taperloc Microplasty	269	100%	1 (0.37%)	1 sepsis	1 intraoperative fracture type 3 debridement wound tissue 2 cup revision loosening 1 sepsis
(Gallart et al., 2019)	Taperloc Microplasty	40	N/A	0		1 posterior femoral cortical perforation 1 infection 1 dislocation 1 subsidence
(Lombardi et al., 2021)	Taperloc Microplasty	92	N/A	2 (2.17%)	1 periprosthetic fracture 1 infection	1 periprosthetic fracture 1 infection 1 non healing wound
(Hayama et al., 2020)	Taperloc Microplasty	257	N/A	0		1 intraoperative great trochanter fracture 1 acute infection 1 dislocation
(Uçan et al., 2021)	Taperloc Microplasty	40	N/A	0		2 intraoperative periprosthetic fracture
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	N/A	0		1 intraoperative fracture 1 subsidence
(Uemura et al., 2021)	CentPillar GB	198	99%	2 (0.9%)	1 aseptic loosening 1 infection	1 intraoperative periprosthetic fracture 1 aseptic loosening 1 infection 2 subsidence
	CentPillar TMZF	24				
(Sariali et al., 2017)	Symbios SPS	154	97%	0		1 dislocation 1 lower limb discrepancy 2 intraoperative periprosthetic fractures
(Tostain et al., 2019)	Symbios SPS	61	96%	3 (4.91%)	2 periprosthetic fracture 1 dislocation	1 dislocation 2 infections 2 periprosthetic fractures
(Graceffa, 2016)	CLS Brevius	170	99.4%	1 (0.6%)	1 major subsidence	3 calcar cracks 2 dislocations 5 DVT 1 subsidence
(Drosos et al., 2020)	Minima S	61	N/A	0		1DVT
(Morales De Cano et al., 2014)	GTS Biomet	81	N/A	0		1 intraoperative femoral calcar crack
(Thalmann et al., 2019)	Fitmore	96	99%	0		1 dislocation 1 deep infection 1 hematoma

TABLE 3.

Component Survivorship, Revision and Complication rates

(Acklin et al., 2016)	Fitmore	28	N/A	3 (10.7%)	1 aseptic loosening 1 unidentified thigh pain 1 infection	1 aseptic loosening 1 unidentified thigh pain 1 infection
(Maier et al., 2015)	Fitmore	100	100%	0		1 hematoma
(Hochreiter et al., 2020)	Optimys	46	N/A	0		1 perioperative dislocation
(Djebara et al., 2021)	Optimys	47	N/A	0		0
(Kutzner et al., 2019)	Optimys	201	N/A	1 (0.5%)	1 deep infection	1 intraoperative great trochanter fracture 1 DVT 1 dislocation 1 infection
(de Waard et al., 2021)	Optimys	34	N/A	1 (2.9%)	1 deep infection	1 infection
(Donner et al., 2019)	Optimys	102	N/A	0		1 intraoperative avulsion of great trochanter 1 DVT 3 seromas

prone to distal stem stabilization, and thus there are less possibilities to achieve rigid primary fixation and bone ingrowth when using metaphyseal fitting short stems, which is in alignment with clinical and biomechanical studies (28–34).

In terms of functional outcome, our results indicate that the shortened tapered wedge stems, with metaphyseal only or metaphyseal-proximally diaphyseal fitting provide excellent results in short- and mid- term follow up. This review found a mean HHS improvement of 45.54 points, from 45.72 (27.29 – 60) preoperatively to 91.44 (83.1-100) postoperatively at 45.54 months follow up. These results are similar with other systematic reviews and metanalysis of short stem studies (10,13,24) and conventional length prothesis studies (35,36). Guo et al. (8) compared Tri-Lock BPS with conventional standard Corail stem (Johnson & Johnson, Warsaw, IN,USA) demonstrating no statistically significant difference in WOMAC score between the two groups, 5.58 ± 2.32 and 6.48 ± 2.32 in 4 years follow up, respectively, beside lower occurrence of thigh pain in the first group (no patients), while 5% in the second one. Higher rate of thigh pain in conventional group (p=0.003), due to tight distal fit of the stem, was presented by Pogliacomi et al. (33). Amendola et. al. (12) assessed the results of the Tri-Lock BPS in 261 hips at a mean follow up of three years and showed high incidence (22.6% of patients) of thigh pain although the HHS improved from 47 to 88. To our knowledge, there are no previous studies on metaphyseal fitting short stems, reporting such high rates of thigh pain. In this review, low incidence of thigh pain (6.02%) was observed. Lastly, Hayashi et al. (30) in their risk factor analysis regarding the incidence of thigh pain following total hip arthroplasty with short, tapered-wedge stem showed that the profile of patients with thigh pain consists of higher UCLA activity, type C Dorr femoral bone shape and contact between stem tip and cortical bone.

Regarding coronal alignment of short stems, a higher rate of coronal misalignment has been observed compared to the conventional standard length femoral implants (10). Lidder et al. (24) presented 90% of neutral alignment between different types of short stems. On the contrary, in this systematic review, 12 studies reported on stem alignment with only 63.6% of the components being in neutral position at the final follow up. In our previous comparative study between Tri-Lock BPS and Minima S stem, a high rate of deviations from neutral position was demonstrated, with the discrepancies being more evident in Minima S group, which is explained by its shorter design and its limited extension to the proximal diaphysis. However, functional outcomes and survivorship were not affected, between the misaligned components compared to those in neutral position, in accordance with previous reports of Albers et al. and Ulivi et al. (37–39).

Stress shielding effect is theoretically limited in

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TABLE 4.

Coronal alignment of femoral components

STUDY	Stem Type	No Hips	Neutral	Varus	Valgus
(Zhen *et al.*, 2021)	Trilock BPS	42	40 (95.2%)	1 (2.3%)	1 (2.3%)
(Ulivi *et al.*, 2017)	Trilock BPS	163	2 (1.2%)	56 (34.3%)	105 (64.4%)
(Albers *et al.*, 2015)	Trilock BPS	123	29 (23.0%)	11 (8.9%)	83 (67.5%)
(Slullitel *et al.*, 2020)	Trilock BPS	46	41 (89%)	4 (8%)	1 (2%)
(Tatani *et al.*, 2020)	Trilock BPS	45	16 (35.6%)	23 (51.1%)	6 (13.3%)
	lima	45	0	27 (60%)	18 (40%)
(Guo *et al.*, 2021)	Trilock BPS	104	74 (88%)	8 (10%)	2 (2%)
(Peng et al., 2021)	Trilock BPS	55	53 (96.4%)	1 (1.8%)	1 (1.8%)
(Hayama et al., 2020)	Taperloc Microplasty	257	246 (96%)	0	11 (4%)
(Graceffa, 2016)	CLS Brevius	170	150 (88%)	16 (9.4%)	4 (2.3%)
(Uçan et al., 2021)	Taperloc Microplasty	40	8 (20%) (− 1.4° ± 3.1)		
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	0.8° (0.0°–1.5°)		
de Waard et al., 2021)	Optimys	34	−0.02 (−0.21-0.17)		

shortened tapered-wedge stems due to more natural biomechanical loading, and more pronounced proximal load transfer. However, comparative studies of short femoral implants and conventional femoral designs note evidence of bone resorption, which is less at Gruen zone 1 and 7 in the case of short stems (5,8,36,40). In 14 studies, included in our review, estimated cumulative combined component stress shielding effect noted in 69.7% affecting especially Gruen 1 and 7 regions. Drosos et al. (41) studying Mínima S component observed stress shielding of grade 1 in all patients, without affecting functional outcome. Amendola et. al. (42) reported similar findings in a series of 212 Tri-Lock BPS implanted hips. Kutzner et. al. (43) demonstrated as well high incidence of proximal bone remodeling due to stress shielding (42.3% bone resorption), particularly in Gruen zones 1, 2 and 7, which was interpreted by the lack of a distal third point of stabilization and by varus alignment of the implants. Nevertheless, biomechanical studies have shown that the incidence of stress shielding depends on the proximal femoral morphology, because short tapered-wedge stems perform better in Dorr type A femurs (44,45). Regarding to Optimys stem, Hochreiter et. al. (46) prospectively studied the periprosthetic BMD, which was found increased from 12.1 to 25.5% in the short stem group in the lateral part (Gruen regions 2 and region 3) and distal part (Gruen region 5) at 24 months follow up, indicating existed proximal and lateral payload, which reduced stress shielding. However, stress shielding effect does not seem to be an unknown phenomenon in short femoral components since a proximal unloading of the femur is still present.

Subsidence of femoral component has been observed in short stems, fluctuating between 0-6.5% (24). Khanuja et al. reported a mean rate of stem subsidence between 0 - 0.6% in type 4 of short stems (10). In our results, we noted a mean of 0.36 mm (0 - 1.93 mm) subsidence. In 2 out of 6 patients with major subsidence >2 mm, revision of femoral component was performed (19,47). Albers et. al. (38) related the subsidence of femoral component (0.41± 0.69 mm) to design features and rough, po-

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TABLE 5.

Radiological parameters assessed in the reviewed studies at the last follow up

STUDY	Stem type	No hips	Osteointegration	Ectopic ossification	Radiolucent line <1 mm	Osteolysis	Subsedence (mm)	Aseptic loosening	Cortical Hypertrophy	Pedestal formation	STRESS-SHIELDING Grade 1	Grade 2	Grade 3	Grade 4
(Hayashi et al., 2020)	Trilock BPS	222	N/A	N/A	101 (45.5%)	N/A	N/A	N/A	30 (13.5%)	N/A	211 (95%)		2 (0.9%)	0
(Zhen *et al.*, 2021)	Trilock BPS	42	42 (100%)	N/A	N/A	N/A	0.39 ± 0.21	N/A	18 (G3/G5)	N/A	40 (95%)	0	0	0
(Ulivi *et al.*, 2017)	Trilock BPS	163	N/A	2 (1.22%)	1 (0.61%) (G3/G4/G5)	0	0.94±0.5	N/A	9 (5.5%) (G2/G6)	10 (6.2%)	N/A	N/A	N/A	N/A
(Albers *et al.*, 2015)	Trilock BPS	123	123 (100%)	N/A	N/A	N/A	1.04 ± 0.73 1 major	1	N/A	N/A	N/A	N/A	N/A	N/A
(Slullitel *et al.*, 2020)	Trilock BPS	46	N/A	N/A	1 (2.17%) (G2/G7)	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A
(Amendola *et al.*, 2017)	Trilock BPS	217	217 (100%)	2 (0.92%)	N/A	N/A	N/A	N/A	4 (2%)	13	135 (64%)	1 (0.5%)	0	0
(Tatani *et al.*, 2020)	Trilock BPS	45	45 (100%)	6 (13.3%)	0	0	0.87±0.56	0	1(2.2%) (G5)	2 (4.4%)	21 (46.6%)	5 (1.11%)	0	0
	Minima S	45	45 (100%)	3 (6.7%)	0	0	0.80±0.69	0	0	0	12 (26.67%)	1 (2.22%)	0	0
(Guo *et al.*, 2021)	Trilock BPS	104	N/A	4 (5%)	1 (1%)	0	0	0	N/A	N/A	63 (76%)	15 (5%)	6 (9%)	0
(Peng et al., 2021)	Trilock BPS	55	53 (96.4%)	0	0	0	0	0	N/A	N/A	32 (58.2%)	23 (41.8%)	0	0
(Schilcher et al., 2017)	Taperloc Microplasty	30	30 (100%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Saragaglia et al. 2020)	Taperloc Microplasty	119	N/A	N/A	0	6 (5%)	0.15±2.8	N/A	0	9 (7.5%)	N/A	N/A	N/A	N/A
(Nahas et al., 2018)	Taperloc Microplasty	196	N/A	N/A	N/A	N/A	1 major	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Gallart et al., 2019)	Taperloc Microplasty	40	N/A	N/A	1 (2.5%) (G1, G3)	0	1 major	N/A	N/A	1 (2.5%)	N/A	N/A	N/A	N/A
(Lombardi et al. 2021)	Taperloc Microplasty	92	N/A	0	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
(Hayama et al., 2020)	Taperloc Microplasty	257	257 (100%)	N/A	N/A	N/A	0	0	24(11%) (G3/G5)	N/A	177 (69%)	80 (31%)	0	0
(Uçan et al., 2021)	Taperloc Microplasty	40	N/A	N/A	N/A	N/A	1.4±0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	N/A	N/A	N/A	N/A	1 major	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Uemura et al., 2021)	CentPillar GB	198	N/A	N/A	47 (27.3%) (G1, G3)	N/A	2 majors	1	N/A	N/A	62 (31.3%)	80 (40.4%)		1 (0.5%)
	CentPillar TMZF	24	N/A	N/A		N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Graceffa, 2016)	CLS Brevius	170	N/A	7 (4%)	0	0	1 major	0	4 (2.3%) (G2)	21 (12%)	N/A	N/A	N/A	N/A
(Tostain et al., 2019)	Symbios SPS	61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A
(Drosos et al., 2020)	Minima S	61	N/A	11 (17.6%)	0	N/A	1.8±0.9	N/A	4 (6.6)	N/A	61 (100%)	N/A	N/A	N/A
(Morales De Cano et al. 2014)	GTS Biomet	81	N/A	N/A	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Thalmann et al., 2019)	Fitmore	96	N/A	N/A	21 (22%)	72 (75%)	1.93±1.72	N/A	71%	N/A	54 (56%)	N/A	N/A	N/A
(Acklin et al., 2016)	Fitmore	28	N/A	N/A	N/A	N/A	0.39 (-2.3-0.5)	1	N/A	N/A	N/A	N/A	N/A	N/A
(Maier et al., 2015)	Fitmore	100	100 (100%)	15 (19%)	20 (25%) (G1, G5, G7)	0	N/A	0	50 (63%) (G3/G5)	N/A	N/A	N/A	N/A	N/A
(Kutzner et al., 2019)	Optimys	201	N/A	2 (1%)	2(1%)	0	15.70% (<2mm)	N/A	9 (4.5%) (G3/G5)	N/A	85 (42.3%)	N/A	N/A	N/A
de Waard et al., 2021)	Optimys	34	N/A	N/A	N/A	N/A	0.16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Donner et al., 2019)	Optimys	102	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Major – subsidence >2mm, G – Gruen zone

rous coating of Tri-Lock BPS, without noting correlations with Dorr type of bone and surgical approach. Fitmore femoral stem demonstrated subsidence of 1.6±1.6mm after 1 year and 1.93±1.7mm after 5 years, and a correlation was found between the amount of stem subsidence and the incidence of cortical hypertrophy (23,48).

While a previous systematic review of short stems reported 98.6% (92-100%) survival rate at a mean follow-up of 12.1 years (24), in our study the estimated combined component survivorship calculated 99% (96-100%) in an average period of 66.3 months. Uemura et. al. (20) was the outlier of follow up time, as they estimated through Kaplan–Meier analysis, that the two tapered-wedge short stems CentPillar GB and TMZF, which differentiate only in their porous coating material, have 99% overall cumulative survival rate at 15 years, which is increased in 99.5% when infection is excluded. Furthermore, we noted that the combined component survivorship was 99.4 in 69.42 months average, when the two studies of Symbios SPS were excluded, because they were the only ones reporting survival less than 98.8%, and specifically 97% and 96% by Sariali et al. (49) who reported 1 dislocation, 1 lower limb discrepancy, 2 intraoperative periprosthetic fractures and by Tostain et al. (50) who presented 4.91% revisions due to 2 periprosthetic fracture and 1 dislocation, respectively.

In this systematic review, the cumulative revision rate was calculated 0.03% (0 – 10.7%). The reported main reasons for revision were deep infection (0.2%), recurrent dislocation (0.12%), periprosthetic fracture (0.12%), aseptic loosening, major unidentified thigh pain and major subsidence. Zhang et al. (5) presented no significant difference in revision rates between short stems and conventional length stems. Australian registry presented that the ten-year cumulative revision rate for THA using a short component was 5.9% (1). Concerning complications, they are low, but not limited in modern femoral prothesis. We noted dislocation in 0.57% and deep infection in 0.39% of the included patients. Intraoperative fractures remain a problem beside the shorter stem length, however Uemura et. al. (20) suggested that the use of three-dimensional preoperative planning has led to low incidence of periprosthetic fractures.

This study, however, has certain limitations. At first, a lot of articles were excluded due to lack of data annotation. Secondly, there is a relatively small number of femoral prostheses in some of the included studies. Furthermore, even if we restricted our research to a specific category of short stems, we could not determine possible outcome differences with respect to specific design variations of each prosthesis. Next, we acknowledge that most of the included studies only presented short- term results, and, for the evaluation of the performance of femoral implants long term results are needed. Finally, as a natural limitation of every systematic review, the quality of data depends on the publications included. In this systematic review only 5 out of 36 studies were Level of Evidence I.

To sum up this systematic review demonstrated that tapered-wedge short stems with metaphyseal or meta- diaphyseal fitting, which require conventional osteotomy offer excellent short to mid-term clinical outcomes and similar revision and complication rates, equivalent to those offered by conventional length or other types of short femoral components. Excellent survival rate (99%) was recorded in 5.5 years with the use of modern short stems. Nevertheless, concerns have been raised regarding the incidence of stress shielding phenomenon and coronal stem malalignment, that need careful evaluation in well-designed high-quality randomized trials with large cohorts and long-term follow-up.

Conflict of interest
The authors declare no conflicts of interest

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Rapid recovery protocol after Total Hip and Knee Arthroplasty that is safe and effective in most clinical environments

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ABSTRACT

Background: Rapid recovery protocols, as well as minimally invasive techniques, are used in daily practice in almost all surgical specialties. Rapid Rehabilitation Protocols are the most modern multifactorial approach for patients with hip, knee or spine surgery. Fast track protocols consist of a combination of minimally invasive surgical techniques, modified anesthesia, staged and personalized analgesia. These protocols have a steep learning curve and require the cooperation of all involved specialties (Orthopaedic surgeon, anesthesiologist, physiotherapist, nursing staff).

Material and Methods: The study was conducted simultaneously at the 2nd Orthopaedic Department of the National & Kapodistrian University of Athens, and other private hospitals for a period of 7 years (2013-2020). In total, 826 arthroplasties were performed by the senior author (GCB), of which 515 were total hip arthroplasties (THA) and 311 total knee arthroplasties (TKA). The patients underwent combined spinal, epidural and intravenous general anesthesia with preservation of automatic breathing as it is considered to contribute to decreased length of stay (LOS), short-term complications, and transfusions. The rapid recovery protocol includes minimal invasive techniques, use of local infiltration anesthesia (LIA), use of tranexamic acid, low transfusion threshold, early mobilization, and immediate initiation of oral nutrition as well as complete abstinence from intravenous or intramuscular opioids that may cause nausea and vomiting.

Results: LOS range was 0-2 days for THAs with mean value: 1.33, and 1-2 days for TKAs with mean value: 1.54. Transfusion with 1 unit of packed Red Blood Cells (PRBCs) was carried out for 14 patients undergoing THA (2.7%), and 4 patients undergoing TKA (1.3%). The difference in hemoglobin values preoperative and postoperative was -2.47 g/dL for THAs and -1.83 g/dL for TKAs. Two THA patients (0.3%) were re-admit-

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ted on day 17 with acute infection and were treated with DAIR and exchange of the modular parts of the arthroplasty. One patient (0.2%) was re-admitted on day 25 due to anterior dislocation and 2 more patients had posterior dislocations. All cases were treated with closed reduction and were discharged at home on the same or next day. Another patient had recurrent dislocations and is scheduled for revision. Two TKA patients (0.6%) were re-admitted on day 15 and 18 with acute PJI and were treated successfully with DAIR. One patient (0.4%) was admitted on day 21 with periprosthetic fracture of the femur, related to a fall, treated with ORIF. One patient (0.4%) was admitted 2 months post-op with periprosthetic joint infection, treated with 2-stage revision (using a spacer). One elderly patient died at home on the 3rd postop day due to MI.
Conclusions: Rapid recovery protocols are feasible and can be applied both at academic departments within NHS as well as private clinics. “Ownership” of these protocols by a small team of surgeons, anesthetists, physiotherapists and nursing staff is the most important requirement for success.

KEYWORDS: Total Hip Arthroplasty; Total Knee Arthroplasty; rapid recovery; rapid rehabilitation

Background

Rapid recovery protocols as well as minimally invasive techniques are now used in all surgical specialties. The first official report was made by the Danish surgeon Henrik Kehlet in 1997 [1]. ERAS protocols in the beginning were used in patients who underwent abdominal and rectal surgery. Bardram studied nine cases of patients receiving epidural anesthesia, early mobilization, and immediate initiation of oral nutrition in the context of a rapid recovery protocol [2]. The reduction of the postoperative pain contributes to the patients’ better rehabilitation. The number of the postoperative complications decreases and as a result the hospital stay.

Rapid Rehabilitation Protocols are the most modern multifactorial approach for patients with hip, knee, or spine surgery. Fast track protocols are a combination of minimally invasive surgical techniques, modified anesthesia, staged analgesia, and personalized nutrition. These protocols have a large learning curve and require the cooperation of many different specialties (orthopedic surgeon, anesthesiologist, physiotherapist, nursing staff). The number of patients undergoing primary total hip or knee arthroplasty continues to increase with costs remaining high for the public health system [3]. Not only is cost reduction necessary but also newer practices require shorter length of stay. The reduction of postoperative complications, readmission rate, and improved functional recovery are the goals of the fast-track protocols [3,4]. ERAS protocols include preoperative, intraoperative and postoperative interventions [5].

Current rapid recovery protocols are difficult because they involve many processes that are complicated, costly and time consuming. In the present study we present a simplified protocol with no inclusion criteria that is feasible for many, if all, clinical environments.

Materials and Methods

Between 2013-2020, we retrospectively collected data of unilateral total hip (THA) and knee arthroplasties (TKA) conducted at a university and a private clinic. There were no inclusion criteria; all patients that had no contra-indication to undergo THA or TKA were included in the study.

A total of 470 patients (155 men, 315 women) 27-94 years old (mean: 68.4) underwent 515 THAs and 287 patients (49 men, 238 women) 27-94 years old (mean: 74.7) underwent 311 TKAs. The surgeon conducted preoperatively proper education of the procedures following surgery, the rapid recovery protocol, management of the expectations of the patient and discharge planning [6, 7, 8, 9, 10, 11, 12, 13, 14, 15]. Pre-operative evaluation was arranged about 7-10 days before surgery at the university clinic and

1-2 days before surgery at the private clinics.

All patients signed an informed consent. Pre-operative evaluation included a thorough interview with the patient about their history, blood tests, 12 lead ECG and chest, lumbar spine, pelvis/knee x-rays using a magnification ball, and if necessary, a full leg x-ray to check leg length discrepancy. At all instances the patient was informed about the rapid recovery protocol and that he/she will walk after surgery and leave hospital next day.

Preoperative planning was performed in all 100% of the cases to ensure the correct choice of the size and type of prostheses, their proper placement within a short OR time.

Patients were advised to bathe with povidone-iodine the night before surgery, to reduce the population of skin microorganisms. Pre-surgery fasting of about 6-8 hours before surgery was advised [16]. The patients were admitted on surgery day.

Two hours prior to incision, chemoprophylaxis with Vancomycin 15 mg/Kg is administered intravenously, due to the extended infusion time [17, 18].

The patient underwent combined spinal, epidural and intravenous general anesthesia with preservation of automatic breathing [19], although modern general anesthesia techniques with limitation of narcotics and certain inhalants can be also used [20]. In THAs the spinal anesthesia was performed at L2-L3 or L3-L4 spaces with administration of 15 μg of fentanyl and 13 mg Ropivacaine 0.75%. In TKAs, spinal anesthesia was performed at T12-L1 or L1-L2 spaces. In THAs the epidural catheter was removed immediately after surgery. In TKAs, the epidural catheter remained for analgesia with administration of fentanyl 3 μg/mL and ropivacaine 0.2% 2 mg/mL with flow 2-3 mL/hour.

Fifteen minutes before surgery, dexamethasone 8 mg is administered intravenously, to reduce postoperative nausea, vomiting and acute pain [21], Cefuroxime axetil 1.5 g IV as chemoprophylaxis and IV Tranexamic acid (TXA) 15 mg/Kg for blood loss control [22]. IV administration of TXA was repeated 3 hours later. TXA was also administered intra-articularly (3g, after closure of the fascia, with closed drainage), to reduce hemorrhage and the need for transfusion with blood [23].

Hypotensive anesthesia further contributes to blood loss control [22]. A tourniquet was used in TKAs, although there are clinical trials suggesting that tourniquet does not reduce the total blood loss from surgery, while having a negative impact on early recovery of muscle strength and lower extremity function [24].

No urethral catheter was used, although it seems that this practice slightly increases the incidence of Postoperative Urinary Retention [25].

Mini posterolateral approach with repair of hip adductors [26] was utilized in THAs using a cementless technique with porous coated acetabular prosthesis and porous coated 3D tapered or (HA) fully coated stem. Maximum effort was taken to avoid length discrepancies [27].

A medial parapatellar approach was used in TKAs. The implant utilized in TKAs was always cemented posterior stabilized femoral component and rotating platform tibial component. Tibial stemed implant was used in obese patients (BMI>35) [28]. However, the ERAS Society makes no recommendations for surgical technique [29].

Local Infiltration Analgesia was utilized in all cases with a cocktail of Bupivacaine 0.5% (24 mL), Morphine sulphate 8 mg (0.8 mL), Epinephrine (1:1000) 300 μg (0.3 mL), Methylprednisolone acetate 40 mg (1 mL), Clonidine 1 μg/Kg, Cefuroxime axetil 750 mg (10 mL) and Sodium chloride 0.9% (to reach volume 60 mL of total solution) [30]. Effectiveness of LIA in reduction of postoperative pain at THAs is ambiguous [31, 32, 33].

Proper hemostasis after tourniquet release and a drainage is also used in TKAs. However, some studies show that not only does it not help prevent hematomas, but it also increases the risk of blood loss because it eliminates the tamponade effect [34, 35]. The drainage remained closed for 2 hours and opened every 2 hours for about 5 minutes.

Warming blankets were used to prevent heat loss, as it is shown that normothermia reduces intraoperative bleeding, cardiovascular complications, and postoperative wound infection [36, 37].

Mobilization begins 1 to 3 hours after surgery: The patient was always motivated by the surgeon to stand up and walk using a walker or crutches.

The patient is also taught how to turn to the side, get out of bed, sit, and walk up and down the stairs. Physical therapy exercises are also shown on day 0 [38].

Tramadol caps 50 mg 1 x 4, Celecoxib caps 200 mg 1 x 2, Acetaminophen 1000 mg IV 1 x 3 were administered on day 0 for the management of postoperative pain. There was a strict order for complete abstinence of intravenous or intramuscular opioids to prevent nausea and vomiting [20].

To reduce postoperative pain, swelling and blood loss, ice-therapy was used in TKAs for at least 20 min every 4 hours, not counting sleeping hours. [39]

Transfusion threshold for most patients was kept at 8 g/dL. Patients with postoperative HGB < 8 g/dL seem to have longer hospital stay and greater rates of readmissions [40]. Patients underwent according to protocol a blood check for HCT, HGB and PLT in the afternoon of day 0 and in the morning of day 1.

Anticoagulation medication started 6-10 hours after surgery with administration of Enoxaparin 4000 IU SC once, continued by Apixaban tab 2.5 mg twice daily from day 1 and for a total of 30 days.[41]

Patients were discharged home if proper pain management and mobilization was achieved. Discharge criteria for all patients were: the ability to ambulate 25 m at ground level, walk up and down the stairs, get out of bed to standing position, go to bathroom and use of the toilet independently, void independently, tolerate oral diet, maintain vital signs within normal limits without symptoms, satisfactory pain control, abstinence of nausea or vomiting, patient comfort with discharge and appropriate transportation and home assistance [42, 43].

Postoperative pain is managed at home with administration of Acetaminophen tab 1000 mg PRN (no more than 3g/day) for THAs and Acetaminophen tab 1000 mg 1 x 3, Etoricoxib 90 mg 1 x 1 (stop if SAP>160 mm Hg), Tramadol caps 50 mg 1 x 3 for TKAs.

Close communication with patients via telephone and email or viber ensured patients' safety and satisfaction [44].

Blood tests (HCT, HGB, PLT) were required on 5th post-op day, and, if necessary, on 10th post-op day, to monitor the trend of postoperative anemia. Removal of sutures (if applicable) was arranged on day 17. Clinical and radiological reassessment arranged at the 1st, 3rd and 12th postop months.

Results

The length of stay was 0-2 days for THAs with mean value of 1.33 days, and 1-2 days for TKAs with mean of 1.54 days. All patients were mobilized successfully on day 0, 1 to 3 hours after surgery. Postoperative Urinary Retention was noted in 10 cases necessitating catheter placement.

Transfusion with 1 RBC was carried out for 14 patients undergoing THA (2.7%), and in 4 patients undergoing TKA (1.3%). Due to early transfusion on day 0 or 1, no delay of discharge was noted.

Five TKA patients developed postoperative transient drop foot that occurred in the evening of day) and recovered next morning. These patients were discharged on day 2.

ΔHGB (difference of HGB at discharge from pre-surgery) for THAs was -2.47 g/dL and for TKAs -1.83 g/dL.

Two THA patients (0.3%) were re-admitted on day 17 with acute infection and were treated with DAIR and exchange of the modular parts of the arthroplasty. One patient (0.2%) was re-admitted on day 25 due to anterior dislocation and 2 more patients had posterior dislocations. All cases were treated with closed reduction and were discharged at home on the same or next day. Another patient had recurrent dislocations and is scheduled for revision.

Two TKA patients (0.6%) were re-admitted on day 15 and 18 with acute PJI and were treated successfully with DAIR. One patient (0.4%) was admitted on day 21 with periprosthetic fracture of the femur, related to a fall, treated with ORIF. One patient (0.4%) was admitted 2 months post-op with periprosthetic joint infection, treated with 2-stage revision (using a spacer).

One elderly patient died at home on the 3rd postop day due to MI.

There were no patients lost at the follow-up.

Discussion

In our study all patients underwent combined anesthesia (spinal, epidural and intravenous general anesthesia with preservation of automatic breathing). General anesthesia with use of fentanyl and propofol, succinylcholine or rocuronium only for intubation, and sevoflurane for maintenance of anesthesia, is also a comparable and acceptable method for rapid recovery protocols at least in THAs. In TKAs epidural anesthesia is a critical part of multimodal analgesic strategy [40].

The use of tourniquet in TKAs to avoid osseous bleeding is necessary during the application of cement to achieve optimum cement technique. Nevertheless, it is not necessary during the whole surgical procedure, if hypotensive epidural anesthesia, optionally augmented by IV epinephrine [45]) is accomplished, resulting in reduced blood loss and transfusion rates [46]. The intraoperative use of tourniquet is recognized as a cause of postoperative pain and reduction in strength of quadriceps for up to 3 months postoperatively [24]. However, Harsten et al showed that, in fast track TKA, not using tourniquet compared to using a tourniquet was not superior in preserving knee-extension strength at the 48-h primary endpoint [47].

Zhang Q et al showed no difference in range of motion, quadriceps strength, total (intraoperative and postoperative) blood loss, hemoglobin drop, superficial wound, or prosthetic joint infection, DVT and hospital stay, with or without the use of a drain [34]. In some cases (eg, atrial fibrillation), in which the patients are on double anticoagulation the use of drainage is strongly recommended to prevent postoperative hematomas. Aspirin as VTE prevention, may probably give surgeons more confidence not to use a drainage after TKA.

Local infiltration analgesia in THAs has been tested by many studies. There is little evidence to support LIA in THA, provided that multimodal oral non-opioid pain treatment is used [49, 50]. On the contrary in TKAs, most trials reported reduced pain and opioid requirements when LIA was utilized compared with a control group treated with placebo / no injection [51]. LIA may provide postoperative pain relief 6-12 hours after surgery [52].

Current clinical practice has shown that THA as an outpatient procedure is feasible and safe; patients have the surgery in the morning, and in the evening, they are discharged at home with instruction for close monitoring during the early postoperative period. Achieving the same result with TKAs, with satisfactory management of pain without epidural analgesia, since the catheter is removed after 8-12 hours, using only multimodal pain control, is still a true challenge.

Conclusion

Rapid recovery protocols are feasible and can be applied both at private clinics and in academic departments without complicated and costly procedures. "Ownership" of these protocols by a small team of surgeons, anesthetists, physiotherapists and nursing staff is the most important requirement for success.

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No financial support was provided.

Conflict of Interest

There are no conflicts of interest.

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Extended Trochanteric Osteotomy and its Role in Revision Total Hip Arthroplasty

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ABSTRACT

Extended trochanteric osteotomy represents a reliable surgical technique for component extraction of the femur and the management of bone defects, with low failure rates and satisfactory functional outcomes. It is a highly effective procedure that was initially established for the management of large bone defects of the femur (Paprosky III-A and III-B) and for long stem removal. Nowadays, utilization of this technique is closely related to the implantation of long stems.Nevertheless, research studies with longer follow up are required to establish its effectiveness.

KEYWORDS: Extended trochanteric osteotomy, Total hip arthroplasty, Revision hip arthroplasty

Introduction

Total hip arthroplasty (THA) is considered one of the most successful orthopaedic procedures. Nevertheless, some patients will eventually undergo a revision procedure in the short- or long-term. Several factors relevant to the patient, the surgeon and/or the implant may play a significant role in total hip arthroplasty failure.

The revision of a THA is an extremely demanding procedure that requires experience and meticulous pre-operative planning (1). The final clinical outcome depends upon many different factors. For example, patient's age and his/her ability to mobilize post-operatively and follow rehabilitation requirements all affect functional outcome. Moreover, patient demands and expectations should be realistic and a thorough and honest discussion between the surgeon and the patient is crucial in the attempt to achieve the best post-operative outcome and patient satisfaction.

Furthermore, the quality of the existing bone stock of the failed arthroplasty is extremely important (2,3). Acetabular and femoral bone biology and quality should be taken into consideration by the surgeon pre-operatively. The anatomy and geometry of the acetabulum and femur, the bone defects, the diameter and geometry of the canal, the canal configuration, and the thickness of the cortex can all

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Figure 1a. *Integrity and continuity of the muscles (vastus lateralis and medius gluteus) is essential.*

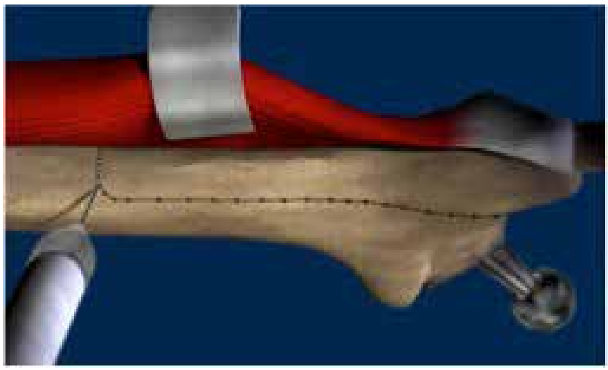

Figure 1b. *Osteotomy is performed with a fine electric saw*

affect the type of the procedure chosen as well as the outcome (2,3).

Another important issue is the removal of the femoral stem. It can be extremely challenging and it should be performed in a way which ensures that bone loss is kept to a minimum. The aavailability and cost of the revision implants, along with the surgeon's experience, have an important influence on the success of the operation.

A successful surgical procedure presupposes detailed, accurate pre-operative planning. Intra-operatively, exposure should be adequate and bone preservation should be one of the first priorities (4,5). Notably, restoration of the axial and rotational stability of the femur and management of existing bone defects are of paramount importance for performing a successful operation.

One of the techniques that commonly accompanies a revision procedure after THA is the extended trochanteric osteotomy (ETO) (4). It is a highly ef-

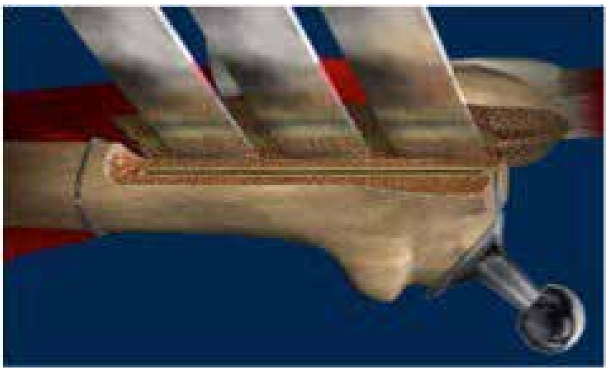

Figure 1c. *Osteotomy is completed with widened osteotomes*

Figure 1d. *Meticulous interface separation is of major importance*

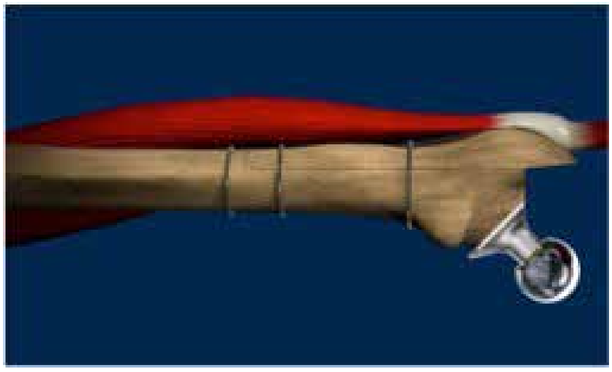

Figure 1e. *Following reduction, the osteotomy is stabilized with wires or cables*

fective procedure that was initially established for the management of large bone defects of the femur (Paprosky III-A and III-B) and for long stem removal. Nowadays, utilization of this technique is closely related to the implantation of long stems.

Surgical Technique

A technically satisfactory osteotomy requires main-

Figure 2. *Bone remodeling in the proximal part of the femur with union of the osteotomy (16 years follow-up)*

tenance of the continuity of soft tissue (gluteus medius and vastus lateralis) (**Figure 1a**), separation of the cortex utilizing a fine electric saw (**Figure 1b**) and utilization of large-wide osteotomes to achieve an appropriate bone window (**Figure 1c**). Widening of the osteotomy should be performed progressively in small, safe steps. A rigorous detachment of the femoral stem and the separation of the bone-implant interface is of major importance, especially in cementless prostheses (**Figure 1d**). Enlargement of the canal is performed to prepare it for reaming. Eventually, the osteotomy is stabilized with wires and cables (**Figure 1e**) (6).

The main advantages of ETO are better exposure and visualization of the femur and soft tissue preservation. It also promotes faster and safer removal of the femoral stem, either cemented or cementless. In case of implant breakage, finding and removal of the fragments is much easier through the osteotomy site. It should be noted that, when the implant has a porous surface, removal without osteotomy is remarkably strenuous and can result in severe bone defects. Subsequently, the use of the osteotomy contributes to the preservation of the bone stock and to smoother component extraction. Over and above this, correction of torsional and other deformities of the femur can also be achieved.

Our Department's Experience

Extended trochanteric osteotomy is widely used in our department in total hip arthroplasty revisions. Between 2000 and 2008, 124 revisions for failure of total hip arthroplasties were performed. There were severe bone defects (Paprosky type IIIA and type IIIB) in 84 of them, while in almost half of the total procedures (61, 49,2%) a trochanteric osteotomy was performed. In all revisions cementless femoral tapered stems with flutes were implanted.

In a follow-up period of 12-20 years (16 years) only 7 cases resulted in a further revision (7/124, 5,6%). Two more suffered from a greater trochanter fracture and subsequent osteotomy failure. All remaining osteotomies, besides these two, united with apparent proximal bone remodeling (**Figure 2**). All patients were prospectively monitored at regular follow ups and satisfactory functional outcomes were observed.

The group of patients with ETO was characterized as group A. Two more groups (groups B and C) were reviewed in comparison with group A. Each of these two groups consisted of 60 patients. All cases were matched for age, gender and side within and across groups. Group B included patients who underwent primary total hip arthroplasty and group C patients who underwent total hip revision due to aseptic loosening. All patients were prospectively monitored and evaluated with HHS (Harris Hip Score), WOMAC (Western Ontario and McMaster Universities Arthritis Index), OHS (Oxford Hip Score) and HOOS (Hip Disability and Osteoarthritis Outcome Score) scales.

Mean values of HHS, WOMAC, OHS and HOOS scales in groups A and C, that included revision cases, were statistically significantly lower than those of Group B who were the primary arthroplasty cases (t-test, p=0.4). In a pairwise comparison between

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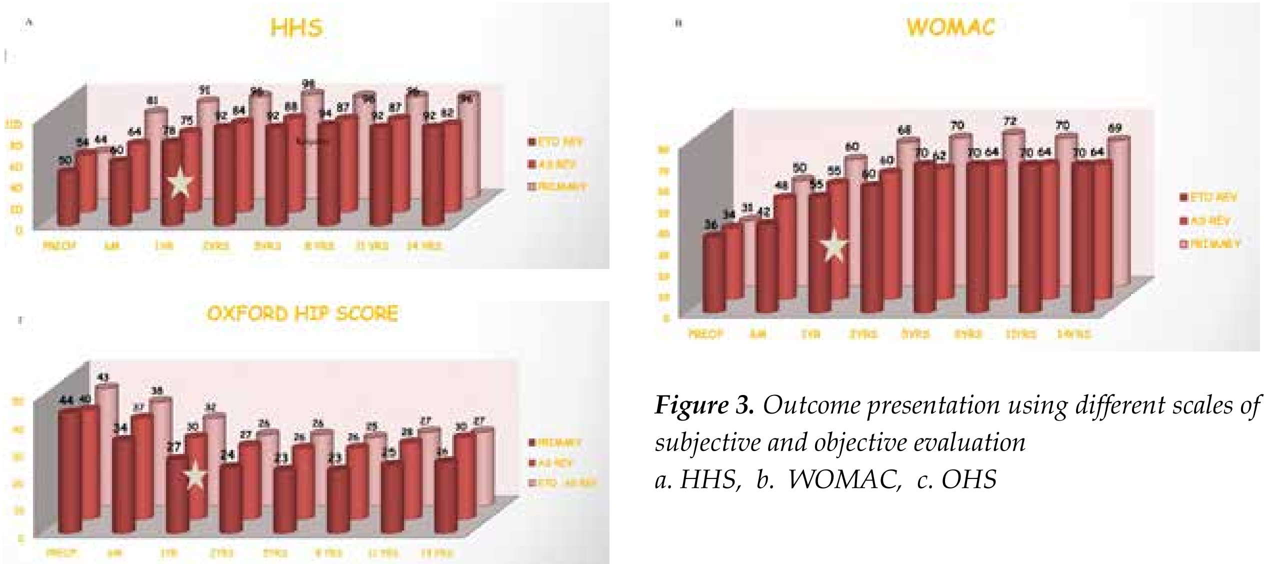

Figure 3. *Outcome presentation using different scales of subjective and objective evaluation*
a. HHS, b. WOMAC, c. OHS

groups A and C, there was a trend for better outcomes in HHS, WOMAC, and OHS scales in the group with ETO, but without achieving significant statistical difference (t-test, p=0.6) (**Figure 3**). However, in parameters of daily activities and quality of life HOOS scale, these were statistically higher in the group that underwent ETO in comparison with the aseptic loosening revision, without ETO, group (t-test, p=0.6) (**Figure 4**).

Discussion

Extended trochanteric osteotomy is commonly performed in cases of femoral stem revision in total hip arthroplasty. Its main indication and benefit is that it facilitates the removal of the femoral stem, either cemented or cementless, and the preservation of bone stock. In general, it has been correlated with the management of large bone defects (mainly Paprosky types IIIa and IIIb) and implantation of long cementless revision stems with distal fixation.

Long-term observation of our series has shown that ETO is a safe and reproducible procedure for component extraction and femur reconstruction in hip revision cases. Failure rate of osteotomies was found to be extremely low and in the majority of cases, bone remodeling was achieved in the proximal part. On top of this, patients who underwent revision with ETO were found to experience better functional outcomes than those who underwent revision without ETO.

Surgical technique is remarkably challenging and demanding. One of the most important factors is the length and extension of the osteotomy. In particular, how long should the distal extension be, and how gradual each step should be, in the attempt to eliminate bone loss (7). The length of the osteotomy is what essentially defines the size and length of the femoral stem that will be implanted. Notably, widening of the osteotomy is a continuing matter of debate.

The indications for ETO are wide and not limited in revision due to aseptic loosening. It can be also used in periprosthetic joint infections (PJIs), especially in cases where removal of the stem cannot be achieved by any other means. Under these circumstances, with periprosthetic infections, ETO is used as a part of the two-stage procedure. The main issue is whether it is safe, since more implants are used, adding an additional burden to infection eradication(8). Nevertheless, published data demonstrate satisfactory infection eradication rates, equivalent to those studies which do not utilize ETO (9).

Another application of the ETO technique is in periprosthetic fractures of the femur following THA. In these cases, a fracture induced osteotomy is usually performed, following the fracture lines. This approach allows access to the implant, with

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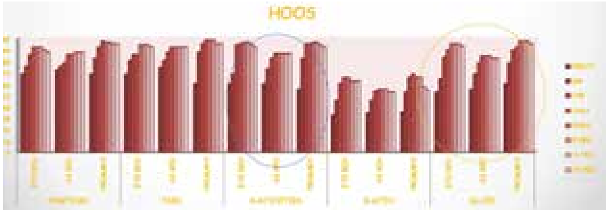

Figure 4. *Results presentation based on HOOS scale*

preservation of the attached soft tissues (5). Application of this method has shown good results, but with short-term follow up, up to 2 years (10).

Utilization of ETO has also been advocated in complex primary hip arthroplasties, such as in cases of existing hardware, significant femur deformations, and congenital hip disease, with promising results (11).

Conclusion

Extended trochanteric osteotomy represents a reliable surgical technique for component extraction of the femur and the management of bone defects, with low failure rates and satisfactory functional outcomes. Nevertheless, research studies with longer follow up are required to establish its effectiveness.

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ACTA
YOUNG SCIENTISTS' PAGES

Conservative versus surgical treatment of spondylodiscitis

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ABSTRACT

Early diagnosis and aggressive initial treatment are essential for a satisfactory outcome of patients with spondylodiscitis. However, management strategies are still controversial. Aiming to compare the results of conservative and surgical treatment of patients with spondylodiscitis, a review of the current literature was conducted by using the online Pubmed database and the following keywords: ("treatment" OR "management" OR "therapy") AND ("vertebral osteomyelitis" OR "spondylodiscitis" OR "spinal infection" OR "discitis"). The search included only comparative prospective or retrospective studies, comparing conservative versus surgical management, in terms of outcome and complications. Initially, 407 studies were identified after a primary search on the online Pubmed database. Finally, 14 studies were included in the review (12 retrospective and 2 prospective studies). In conclusion, the initial treatment of spondylodiscitis should be conservative with bed rest, bracing and proper antibiotic treatment lasting for at least 8 weeks. However, in cases of neurological deficit, abscess formation, deformities and failure of conservative management, surgical treatment is required. Although conservative treatment is associated with a higher rate of chronic back pain and long-term deformities, it is also associated with a lower mortality rate in comparison to surgical management. Perioperative complications still remain an issue in surgically treated patients; however, patients' satisfaction and quality of life are higher compared to those of conservatively treated patients, indicating that treatment of spondylodiscitis should be individualized taking into consideration patients' clinical presentation, imaging studies and the virulence of the responsible pathogen.

Key Words: spondylodiscitis ; vertebral osteomyelitis; spinal infection; treatment; management

Introduction

Spondylodiscitis accounts for 2-7% of all osteomyelitis cases. It affects mainly elderly immunocompromised patients; however, it can also affect young patients in association with HIV infection, immunodeficiency syndrome and intravenous drug use. The most common pathogenic mechanism is hematogenous spread of microorganisms which may occur in any condition that causes bacteremia, such as urogenital, respiratory or soft tissue infection. The most common responsible microorganisms are *Staphylococcus aureus* (30-55%), *E. coli*, *Salmonella, Enterococcus, Proteus mirabilis, Pseudomonas aeruginosa* (65% of intravenous drug users), *Streptococcus viridans* and *Staphylococcus epidermidis* [1].

Typically, the initial symptom is slowly increasing, continuous and localized back or neck pain, which is exacerbated during rest, especially at night. Additional symptoms may include muscle spasms, weight loss, lower back, groin or buttock pain, and in advanced stages of disease symptoms of radiculopathy and myelopathy. Serum inflammation markers such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) are usually increased. While plain X-rays become positive only in the advanced stages of the disease, Magnetic Resonance Imaging (MRI) becomes positive very early in its course and has been established as the imaging method of choice. Lesion biopsy and isolation of the responsible pathogen is highly important and should be attempted in any case. Computed Tomography (CT)-guided biopsy is the method of

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choice because it allows a sample to be taken from the core of the lesion with safety and accuracy [2-4].

Early diagnosis and aggressive conservative or surgical treatment are essential for a satisfactory outcome. The primary goals of management of spondylodiscitis are the isolation of the responsible microorganism, the prevention of bacteremia and sepsis, the elimination of the infection, the long-term pain relief, the prevention or reversal of the neurological deficit, the restoration of spinal stability, the correction of spinal deformity and the prevention of the recurrence of the disease. Initial treatment of bacterial and parasitic infections is usually conservative with bed rest and intravenous administration of antibiotics for at least 4-6 weeks, depending on the extent of the infection and the responsible microorganism. Antibiotic treatment should not be ceased before serum inflammatory markers return to normal. Although bed rest is indicated in the very early stages of treatment, early mobilization of the patient with the help of a brace is recommended. Basic treatment principles also include improving the patient's diet and immune status as well as treating ectopic infections, for example urinary or respiratory tract infections [2, 5-6].

Indications for a shift from conservative to surgical treatment are the persistence or worsening of the infection despite adequate antibiotic treatment and the presence of pharmacological side effects, as renal or hepatic impairment, limiting further use of the appropriate antibiotics in the required dosages. Surgical treatment is also indicated in cases of progressive spinal deformity and instability, formation of spinal abscess or appearance of neurological signs due to nerve compression. Indeed, spinal cord compression requires urgent surgical intervention. However, it may prove useless if the paralysis has been established for more than 24-36 hours [7].

The key to successful surgical treatment is radical surgical debridement. This has been widely proven in the treatment of tuberculous spondylitis, but it also applies in cases of pyogenic spinal discitis. Anterior approach of the spine and radical surgical debridement and reconstruction of the anterior spinal column using bone graft are indicated in patients with intravertebral abscesses without major bone destruction, deformity and instability. Anterior spinal approach is also effective in decompressing the spinal canal if the anterior spinal elements are involved. Posterior spinal fusion after anterior spinal surgery is indicated in cases with significant kyphotic deformity or after radical surgical debridement and corpectomy at multiple levels. Hardware and grafts for spinal fusion can be used at the site of the infection, provided that radical surgical debridement is fully achieved [1, 6-8].

The aim of the current study was to review and compare the results of conservative and surgical treatment of patients with spondylodiscitis. For this reason, a review of the current literature was conducted using the online Pubmed database and following the PRISMA Guidelines. Article titles were searched by using the following keywords: ("treatment" OR "management" OR "therapy") AND ("vertebral osteomyelitis" OR "spondylodiscitis" OR "spinal infection" OR "discitis"). Inclusion criteria in the review were: comparative prospective or retrospective studies, comparing conservative versus surgical management, in terms of outcome and complications. Studies published in non-English language, non-comparative studies, reviews, case reports and study protocols were excluded from the review. Studies in children and adolescents were also excluded. Initially, 407 studies were identified after a primary search on the online Pubmed database. After screening of titles and abstracts, 302 articles were excluded as inappropriate. From the remaining 105 studies, 91 were rejected for various reasons (figure 1), leaving 14 studies for analysis (12 retrospective and 2 prospective studies).

Discussion

<u>Pyogenic Spondylodiscitis</u>

A retrospective study by Karadimas *et al*, compared the results of conservative and surgical treatment in 163 patients hospitalized for spondylodiscitis. Seventy patients received conservative treatment, 56 patients underwent posterior decompression and 37 patients underwent posterior decompression and stabilization. At one-year follow-up, 11% of patients treated conservatively had to be operated, while no one had developed neurological symptoms. Among patients receiving decompression without stabilization, the reoperation rate was 42%, while 26% had developed neurological symptoms. Among patients receiving combined stabilization and decompression, the reop-

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eration rate was 16%, while 30% had developed neurological symptoms. The authors concluded that conservative treatment was effective in 89% of patients with spondylodiscitis, especially in those with mild clinical symptoms and no neurological signs [9].

Similarly, another retrospective comparative study by Valancius *et al*, including 208 patients, described the results of conservative versus surgical treatment of patients with infectious spondylodiscitis. Conservative treatment with antibiotics and bracing was applied in 91 patients, while 94 patients underwent posterior debridement with or without pedicle screw instrumentation and 23 patients underwent anterior debridement with or without pedicle screw instrumentation. The study results showed that the rate of successful conservative treatment was 87%. The authors concluded that administration of antibiotics and bracing is a safe and effective treatment of patients with spondylodiscitis without any complications [10].

In another retrospective observational cohort study including 27 patients with single-level uncomplicated lower thoracic or lumbar pyogenic spondylodiscitis, Nasto *et al*, compared the application of a standard thoracolumbosacral orthosis rigid bracing for 3–4 months (n = 12) with posterior percutaneous pedicle screw spinal instrumentation followed by a soft brace for 4 weeks (n = 15). All patients received resistance-adopted antibiotics. In 6 months follow-up, patients subjected to surgical treatment reported lower pain scores and improved quality of life. However, no statistically significant differences were found in 9 months follow-up. The authors concluded that surgical treatment did not offer any advantage in healing time over thoracolumbosacral orthosis rigid bracing because infection clearance mainly depends on proper antibiotic administration [11].

Wirtz *et al*, in a retrospective study, assessed the therapeutic outcomes of 59 patients with lumbar or thoracic spondylodiscitis. Thirty five patients were treated conservatively with bed rest, bracing and proper antibiotics, while 24 patients underwent surgery, due to abscess formation or progressive neurological deterioration. Mean time of immobilization was 5.9 weeks for patients undergoing surgical procedures and 7.8 weeks for patients treated conservatively. The authors concluded that conservative and surgical treatment are not rivals but rather complementary to one another, as they are both indicated for management of spondylodiscitis [12].

A recent, single center, retrospective cohort study by Alas *et al*, enrolled 116 patients with spondylodiscitis. Seventy three patients received only conservative treatment (antimicrobial treatment and analgesics) and 43 patients received surgical plus conservative treatment. Patients treated surgically were significantly younger and less frail. Surgical treatment was significantly associated with decreased 30-day and 1-year mortality rate in comparison to conservative treatment, while an increased frailty index was associated with higher short-term mortality, regardless of intervention [13].

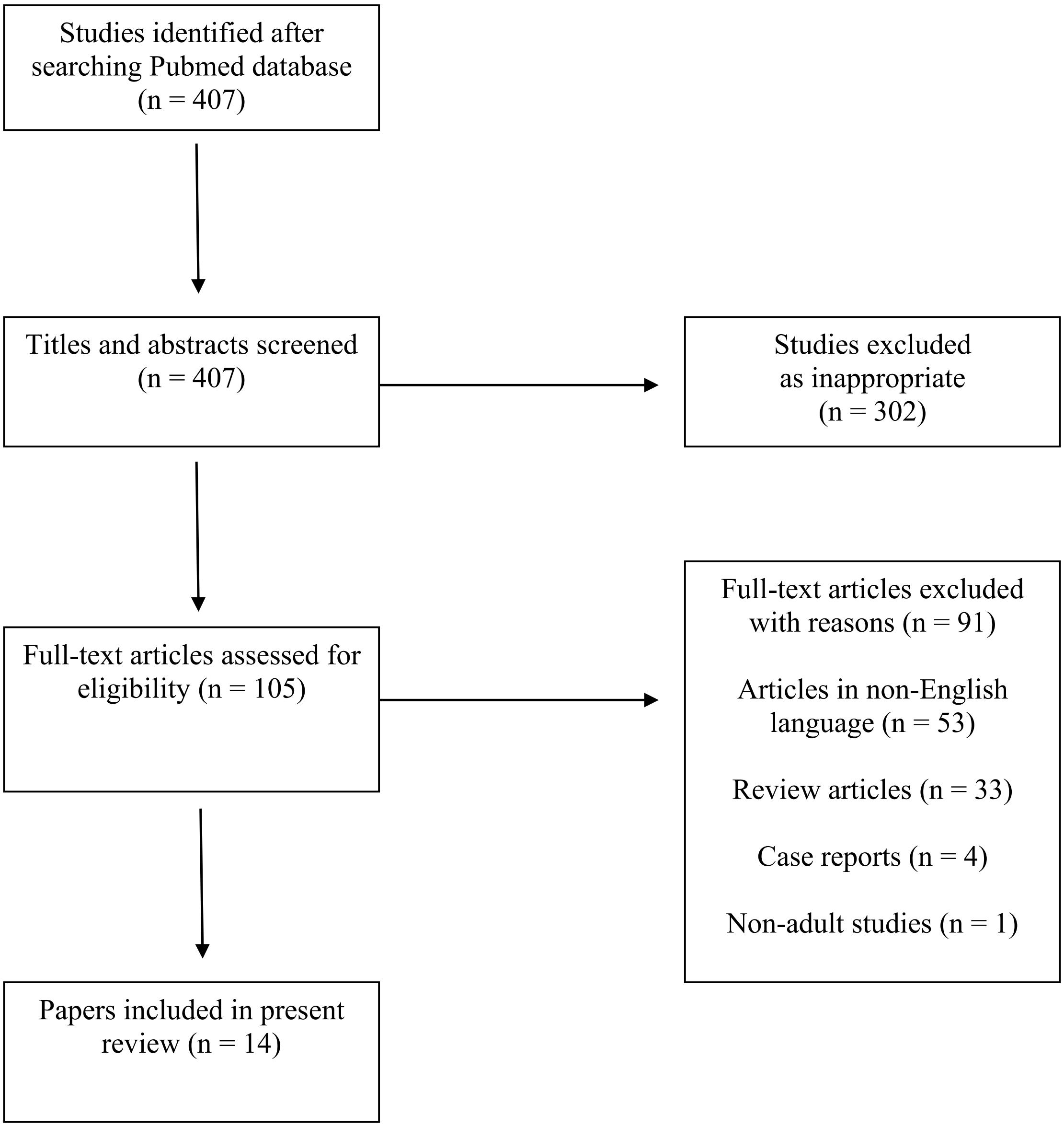
A small prospective study by Waheed et *al*, enrolled 44 patients with spontaneous spondylodiscitis. Twelve patients received conservative treatment with bed rest, bracing and proper antibiotics, 10 patients underwent laminectomy, debridement and open biopsy, and 22 patients underwent laminectomy and fusion. The authors concluded that once diagnosis is confirmed, early and prolonged administration of proper antibiotics is recommended for the treatment of spontaneous spondylodiscitis [14].

Quality of life after surgical and conservative treatment of spondylodiscitis was evaluated in a recent, retrospective, single-center study by Behmanesh *et al*. From 210 patients with spondylodiscitis, 155 underwent a surgical procedure and 55 were treated conservatively. Patients treated surgically reported a significantly improved quality of life in comparison to conservatively managed patients [15]. A similar study by Woertgen et *al*, retrospectively investigated 62 patients with pyogenic spinal infection. Among them, 28 patients underwent conservative management and 34 patients were operated. Patients treated with a surgical procedure reported a slightly better quality of life and self-reported satisfaction levels [16].

<u>Hematogenous pyogenic vertebral osteomyelitis</u>

Another recent retrospective study by Canoui *et al*, evaluated conservative and surgical treatment in 90 patients with hematogenous pyogenic vertebral osteomyelitis. 69% of the patients (n = 62) were treated conservatively, while 31% (n = 28) received a combination of conservative and operative treatment. At

Figure 1. Study flowchart



4-months follow up, although there was no difference in neurological improvement between the two groups, patients treated both surgically and conservatively experienced less pain. However, at one-year follow up, there was no difference in infection-related complications between the two groups [17].

In another retrospective study, Hadjipavlou *et al,* compared the conservative and operative management among 101 patients with hematogenous pyogenic vertebral osteomyelitis. All patients received antibiotics, initially intravenously and then orally. Sixty-six patients received an operation, while the rest were treated conservatively. Among patients treated conservatively, 64.3% continued to report chronic back pain. In the surgically treated group, only 26.3% of the patients reported chronic back pain at disabling levels. The authors concluded that the outcome of treatment depends on the type of infection and the severity of neurologic involvement prior to the treatment. Conservative treatment may control the infection; however, surgery may prevent deformities and chronic back pain [18].

The therapeutic outcomes of hematogenous vertebral osteomyelitis caused by methicillin-resistant Staphylococcus *aureus* were evaluated in a prospective cohort study by Park *et al*. All of the 139 patients received intravenous antibiotics as an initial treatment, for a mean duration of 50 days. Surgical debridement was performed in 40 patients and CT-guided aspiration drainage was performed in 38 patients. At multivariate analysis, surgical debridement was associated with prolonged hospitalization, while longer duration of antibiotic therapy was associated with lower relapse rates [19].

A retrospective multicentre study by Colmenero *et al*, included 219 adult patients with vertebral osteomyelitis. 48% (n = 105) of patients suffered from brucellar vertebral osteomyelitis, 33% (n = 72) suffered from pyogenic vertebral osteomyelitis and 19% (n = 42) suffered from tuberculous vertebral osteomyelitis. Among them, 119 patients received only conservative treatment and 100 patients received both conservative and surgical treatment. The outcome of the operated patients did not differ significantly from that of patients treated only conservatively, although the mean duration of hospitalization was significantly higher in the group of operated patients [20].

<u>HIV-infected patients</u>

In 2009, Sobottke *et al*, conducted a multicenter retrospective study comparing the outcome of surgical versus conservative treatment in HIV(+) patients with spondylodiscitis. The study included 20 patients; 10 were treated conservatively with antimicrobial agents and 10 received an operation. The authors concluded that surgical management of spondylodiscitis in HIV(+) patients is not associated with an increased surgical complication rate. As increased perioperative morbidity is not expected, HIV infection should not affect decision-making regarding conservative or surgical management of spondylodiscitis [21].

<u>Elderly patients</u>

A retrospective case series by Sobottke *et al*, compared conservative and operative treatment of spondylodiscitis in patients over 65 years of age. Sixteen patients were managed conservatively and 16 patients were managed surgically. Neurologic deficit, sepsis, instability, abscess formation and impending deformities were indications for surgery, while conservative treatment was applied in patients with mild symptoms. The authors found that the complication rate of surgical treatment of elderly patients with spondylodiscitis was not higher than that observed in younger patients. No difference was also found regarding pain and quality of life; however, satisfaction was higher in elderly patients receiving operation. The authors concluded that age should not influence the decision making regarding conservative or surgical treatment of patients with spondylodiscitis [22].

In conclusion, initial conservative treatment of uncomplicated spondylodiscitis with bed rest, bracing and proper antibiotics for at least 8 weeks, remains the gold standard. However, in cases of neurological deficit, abscess formation, deformities, and failure of conservative treatment, surgical treatment is required. Conservative treatment is associated with a higher rate of chronic back pain and long-term spinal deformities; however, it is also associated with a lower mortality rate in comparison to surgical treatment. Perioperative complications still remain an issue in surgically treated patients; however, patients' satisfaction and quality of life seems to be higher than those of conservatively treated patients, indicating that treatment of spondylodiscitis should be individualized taking into consideration patients' clinical presentation and imaging studies and the virulence of the responsible pathogen.

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The use of Dexmedetomidine in patients with Spinal Cord Injury

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ABSTRACT

Traumatic Spinal Cord Injury (SCI) may often lead to significant disability in affected individuals and reduce quality of life.

Over 70% of SCI patients suffer from multiple injuries, concomitant with spinal cord trauma, contributing to the high rates of associated complications during the acute and long-term phases of care [1].

SCI impairs body's autonomic and biomechanical performance by interrupting communications between the brain, organ systems, muscles and bones. This carries important implications on patients' ability to perform basic daily-lifeactivities and reserve capacity to withstand illnesses and aging [2].

Dexmedetomidine, an imidazole compound, is a highly selective a2-adrenoreceptor agonist, even ten times more selective than Clonidine. It is a very versatile drug in anaesthesia practice, nowadays applied in increasing number of clinical scenarios. It is an analgesic with anaesthetic sparing effects, sympatholytic properties, applied for procedural sedation, displaying cardiovascular stabilizing properties. It reduces delirium and preserves respiratory function, adding benefits to its use [3].

The aim of this review is to present the evolving role of Dexmedetomidine in patients with Spinal Cord Injuries in anaesthesia and ICU sedation and discuss its limitations.

Key Words: Spinal Cord Injury, Dexmedetomidine, ICU, Surgery

Introduction

Dexmedetomidine is an a2-adrenoreceptor agonist with a broad range of pharmacological properties, reflecting the extensive distribution of a2-receptors throughout the body [4,5], registreted in FDA since 1999. Originally, it was approved for intravenous (iv) administration in the Intensive Care Unit (ICU) during sedation of mechanically ventilated adult patients, for up to 24 hours [2]. In 2008, an additional indication was granted in USA, allowing the use of DEX for the sedation of non-intubated patients prior to and/or during surgical and other procedures. Since 2011, Dexmedetomidine has been approved by the European Union for the sedation of adult ICU patients, requiring a sedation level at which patients remain awake in response to verbal stimulation [3]. It is commercially available as a water-soluble HCL salt under the brand name of Dexdor and Precedex and exerts its hypnotic action through activation of central presynaptic and postsynaptic a2-adrenoceptor in Locus Coeruleus, inducing a state of unconsciousness similar to natural sleep, with minimal respiratory depression [8-13].

The pharmacokinetic characteristics of dexmedetomidine have been reported and examined in many pre-clinical and clinical studies. In healthy adult volunteers, half-life elimination was described at 2.1 to 3.1 hours and the clearance from non-compartmental analysis varied from 0.51 to 0.89 L/min. Likewise, from pre-clinical studies, it was found that the drug distributes rapidly and widely throughout the body and readily crosses the blood-brain and placental barriers [8,14]. Around 94% of Dexmedetomidine is bound to plasma albumin and a1-glycoprotein in healthy volunteers [8,15]. Elimination is performed mainly through glycoronidation in the liver, at its N3 and N1 position of the imidazole ring [16]. The direct N-glucoronidation products of Dexmedetomidine, namely N3- and N1- glucoronide (DG1) and (DG2) are the primary metabolites of Dexmedetomidine, accounting for about 41% of its metabolism in healthy volunteers [8,15], while other metabolites of Dexmedetomidine are N-methyl-O-glucoronidedexmedetomidine, 3-hydroxy dexmedetomidine, glucoronide of 3-hydroxy dexmedetomidine, 3 carboxylic acid dexmedetomidine, and N-methylated carboxylic acid dexmedetomidine [15]. Overall, less than 1% of Dexmedetomidine is excreted unchanged and 95% is eliminated via metabolism and subsequent excretion via urine [8,15]. The pharmacokinetic profile of Dexmedetomidine has been extensively evaluated in various populations and the reports revealed that covariates, including age, frailty, body size, hepatic impairment, plasma albumin, and cardiac output, may have a significant impact on the pharmacokinetics of Dexmedetomidine [9,11,14,16,17]

The aim of this article is to critically review and summarize published data on the clinical application of Dexmedetomidine in patients with Spinal Cord Injury as well as the usefulness of its administration. The MEDLINE database was searched through PubMed. All English articles and abstracts with a title containing the words Spinal Cord Injury, Dexmedetomidine, ICU, surgery were selected. Additional searches were performed including the keywords "interactions" and "analgesia". After screening titles for possible relevance, papers were added to the flowchart. All abstracts were screened and when considered relevant, the papers' full texts were obtained. Bibliographies of articles were reviewed and as such, additional potentially relevant papers were identified and added to the flowchart (Table 1).

Discussion

Injuries to the Spinal column and Spinal Cord frequently occur after high-energy mechanisms of injury, or with lower-energy mechanisms, in selected patient population, like the elderly. A focused, yet complete neurologic evaluation will guide subsequent diagnostic procedures and early supportive measures to help prevent further injury. For patients with osseous and/or ligamentous injury, the initial focus should be spinal immobilization and prevention of Spinal Cord lesions [18]. These injuries may often lead to significant disability in affected individuals and reduce life satisfaction [19]. Patients with Spinal Cord Injuries require multidisciplinary management to achieve optimal health outcomes [20].

Sedation

The sedative effects of Dexmedetomidine are well established. Dose-dependent sedation was seen in healthy volunteers receiving intravenous boluces of Dexmedetomidine 0,25-2μg/kg [21], while the sedative effect of Dexmedetomidine infusion were shown in both healthy volunteers [22-24] and ICU patients [25-28]. The drug induces sleep by decreasing the firing of noradrenic locus Coeruleus neurons in the brain stem and activating endogenous non-rapid eye movement sleep-promoting pathways [29]. It produces a state closely resembling to physiological state-2 sleep [30]. Thus, recipients can be easily roused to participate in testing [24] and cooperate during sedative procedures [30]. Dexmedetomidine has analgesic effects in healthy volunteers [22,24] and opioid-sparing effect in patients in ICU setting [26]. The analgesic effect appears to be exerted at the Spinal Cord level, supraspinal sites, as well as through nonspinal mechanisms [31]. Dexmedetomidine demonstrates sympatholytic activity [22,32-34]. Significant reductions from baseline in plasma noradrenaline (norepinephrine) and/or adrenaline (epinephrine) levels were observed in healthy volunteers [22,32,33] and surgically treated patients, postoperatively [34] .

Side effects are mainly restricted to hemodynamic alterations. These include hypertention, bradycardia, and hypotention, owing to pre- and postsynaptic a2- receptor activation as well as reflex bradycardia [35,36]. Moreover, it has been shown to attenuate stress responses, thereby creating a more stable hemodynamic profile during stressful events, such as surgery or anesthetic induction [37-39].

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Clinical Applications of Dexmedetomidine

A. Intensive Care Unit (ICU)

Stable hemodynamic conditions are crucial for optimal clinical management of patients with acute Spinal Cord Injury, admitted to a neuricritical care unit [40].

Sedation in the ICU works both ways. Although it reduces anxiety and agitation, sedative drug therapy typically diminishes patients' level of arousal, often incites delirium during wakefulness, and may add greater dependence on assisted ventilation and need for hemodynamic support [41]. Dexmedetomidine combines analgesic, sedative and anxiolytic effects while maintaining patients' arousability without significant respiratory depression [42]. It is these characteristics that make this drug a potentially attractive sedative for Spinal Cord Injury (SCI) patients, since they often require awakening for thorough neurological assessment.

The Acute Neurological ICU Sedation Trial (ANIST), an Institutional Review Board-approved investigator initiated prospective, randomized, double-blinded, crossover study, demonstrated that Dexmedetomidine preserves the cognitive state and may improve intellectual function during active sedation, in patients with lower than normal baseline cognition. That was a great note to intensive care practitioners; incorporating strategies that render a calm and cooperative state while not impairing gross intellectual function can, in fact, yield objective improvement both in cognition as well as in functional neurological condition [43]. A recent well-designed randomized controlled-trial presented clinical evidence of adding Dexmedetomidine as an adjuvant agent or as the sole sedative in neurological patients, requiring postoperative mechanical ventilation in the ICU [44]. This study showed that Dexmedetomidine facilitated early extubation and was associated with more ventilator-free hours. It is exceptionally, important in the neurosurgical population, to control agitation and provide analgesia, so as to improve tolerance to mechanical ventilation and accelerate time to extubation, maintain homeostasis and enable early neurological assessment.

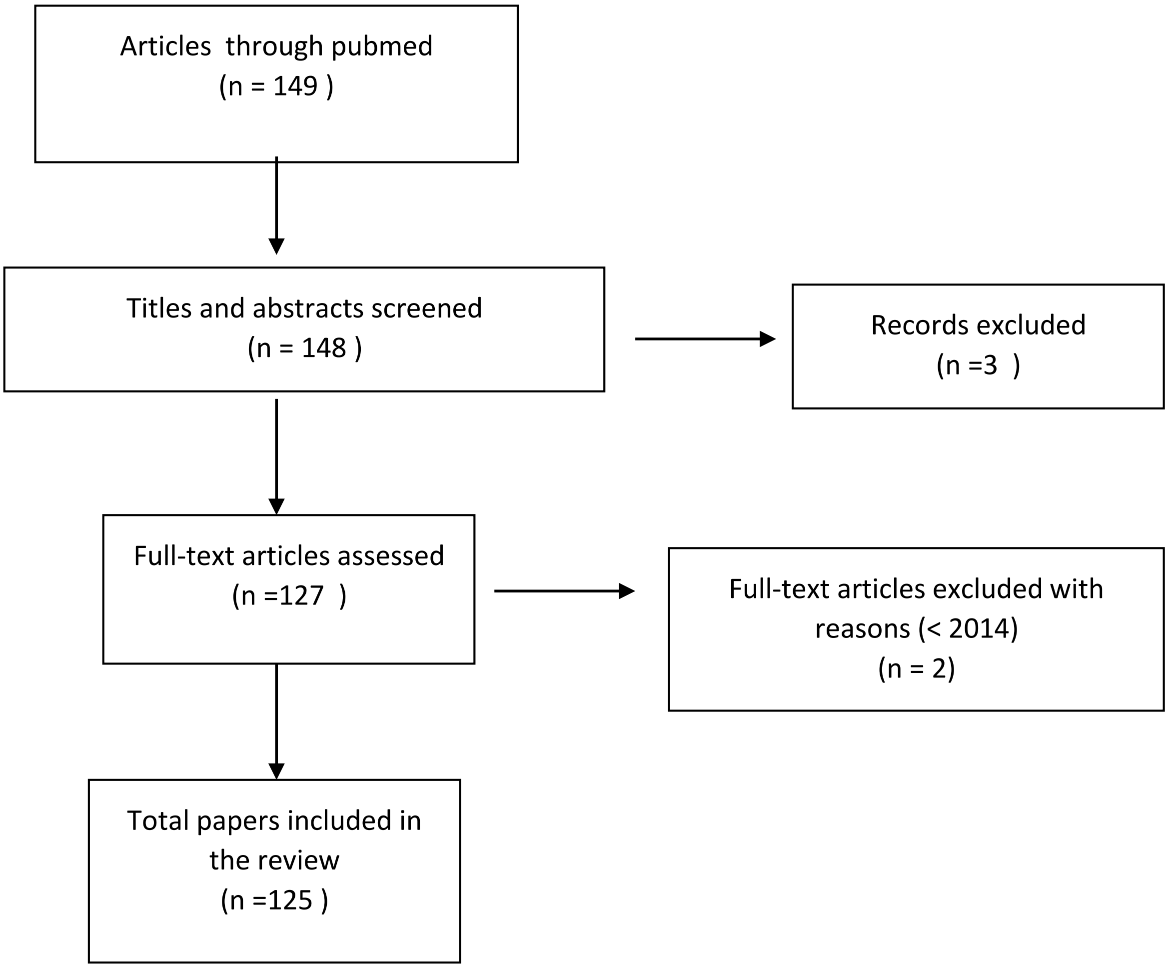
In a prospective randomized control study of 90 neurosurgical patients requiring short-term postoperative ventilation for about 12 hours, Dexmedetomidine, Midazolam or Propofol all provided effective sedation and stable hemodynamic stability. Compared to Propofol and Midazolam sedation, Dexmedetomidine was associated with a longer time to extubation [45]. A retrospective propensity-matched cohort data analysis of 342 patients from 2 medical centers showed that Dexmedetomidine and Propofol were associated with an equal prevalence of hypotention (defined as MAP<60 mmHg, 23% vs 26%) and bradycardia (defined as heart rate <50 beats/min, 8,6% vs 5,5%) [46]. However other studies frequently demonstrate that Dexmedetomidine is more commonly associated with bradycardia [45,47]. The prevailing thought is that Dexmedetomidine may be associated with less hemodynamic perturbation, minimal neurophysiological monitoring interference, greater ability to achieve cooperative sedation without respiratory compromise in awake procedures and acceptable pain control.

B. Surgery

Spinal surgery poses unique challenges concerning the provision of optimum perioperative management. Intraoperative hemodynamic changes, blood loss, requirement of augmented doses of anesthetics or potent opioids to suppress the hemodynamic responses evoked by noxious stimulation and rapid awakening for early neurological assessment, constitute the most prominent intraoperative concerns during spinal procedures [47-50]. Furthermore, spine surgeries are painful and often require significant perioperative analgesia [48,51].

As multiple pathways like nociceptive, inflammatory and neuropathic ones seem to be implicated in the occurrence of pain following major spine surgery, the ideal analgesic strategy for these procedures remains yet an intriguing issue. Aiming to avoid any possible adverse effects, an analgesic approach targeting multiple antinociceptive and antihyperalgesic pathways is considered as the best alternative choice [48,51].

Patients with high cervical lesions can suffer spinal cord injury during tracheal intubation and positioning. Although electrophysiological monitoring techniques can assist early detection, they may not be practical [52,53] and miss certain injuries [54]. With the patient awake, injury may be more easily prevented. Dexmedetomidine is increasingly used to provide sedation for awake fiberoptic intubation, as it maintains spon-



taneous respiration without airway obstruction [55-57]. Furthermore, its offset kinetics provides optimum conditions and fulfills the need of post-intubation neurological examination, required in such patients.

Cervical fixation along with spinal cord decompression is the most commonly performed surgical procedure for patients with cervical SCI. As there is high concern for further neurological damage during head extension and neck flexion for direct laryngoscopic intubation, awake flexible fiberoptic intubation (AFOI) is often the preferred method for airway management [58]. Adequate sedation with topical anesthesia of the airway may minimize undue discomfort, anxiety and sympathetic surge during AFOI, but respiratory depression and hypoxaemia may occur with excessive sedation [59]. Although various pharmacological agents have been used for conscious sedation during AFOI, most of them demonstratee respiratory depressant effect, in higher doses [59,60]. Consequently, there is a need for an ideal sedative agent for AFOI that will allow patients to maintain spontaneous respiration and protect their own airway with full cooperation, during application of the fibreoptic scope. The major advantage of Dexmedetomidine infusion during AFOI is a unique form of sedation where patients with cervical spinal cord injury remain sleepy but are easily aroused and cooperate with minimum respiratory impairment [55,61].

Neurological assessment can be performed immediately following intubation, as patients remain awake throughout the procedure [62]. Episodes of obstructive apnoea have been reported in one study when Dexmedetomidine was infused at 1 and 2 μg/kg rapidly over 2 min [63]. Additionally, episodes of loss of airway

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patency with higher doses of Dexmedetomidine infusion (10 μg/kg) have also been reported [64]. In cases of lower maintenance dose of Dexmedetomidine (0,5 μg/kg), no adverse effects were observed.

Dose-depended biphasic alteration of BP with Dexmedetomidine has been reported [65]. It has been documented that hypertensive episodes are more frequent at higher doses (1-2 μg/kg) and hypotension at lower doses (0,25-0,5 μg/kg), when bolus infusions were administered over 2 min [66]. Initial increase in BP following loading dose may be due to vasoconstriction, caused by direct stimulation of a1- receptors on blood vessels and secondary decrease in BP in the subsequent period, due to inhibition of norepinephrine release from sympathetic terminals [67]. This biphasic BP response can be controlled by increasing the duration of the loading dose (1 μg/kg over 10 min) and lowering the maintenance dose (0,5 μg/kg/h). It has been documented that higher doses of Dexmedetomidine may be used safely with minimal changes in hemodynamics, when they are infused over 10 min [68]. It is also recommended that the use of Dexmedetomidine at 1 μg/kg bolus over 15 min, with maintenance rates of 0.2-0.7 μg/kg/h, is safe and beneficial for surgical patients [69].

C. *Neuroprotective effect*

Interest in the potential protective effects of Dexmedetomidine in relation to spinal cord injuries has grown in the past few years. Recent animal studies have shown that intravenous Dexmedetomidine attenuated spinal ventral neuronal degeneration and preserved neurological function and neuronal viability, following transient spinal cord ischemia [70] or ischemia-reperfusion [71]. These beneficial effects were associated with improved cell survival and antiapoptotic factors, as well as with the attenuation of microglial activation, proinflammatory cytokine production, decreased interleukin-6, tumor necrosis factor-alpha and reduced neurotrophil infiltration, indicating an anti-inflammatory effect [72,73]. In terms of injury biomarkers, a prospective study reported reduced levels of the stress hormone cortisol and the inflammatory response marker interleukin-10 following intraoperative Dexmedetomidine infusion in cervical spine surgery [74].

Conclusion

In the recent years, there has been increasing interest in the application of Dexmedetomidine to various neurological clinical scenarios, especially for SCI patients. Literature data on the use of Dexmedetomidine in the neurocritical patients, as sole sedation or as an adjuvant, supports that the drug is both efficient and safe. It may be associated with less hemodymamic perturbation, minimal neurophysiological monitoring interference, greater ability to achieve cooperative sedation without respiratory compromise in awake procedures and acceptable pain control.

Conflict of interest disclosure

"The authors declared no conflicts of interest".

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Osteoporotic vertebral compression fractures: The effect of Vertebroplasty and Kyphoplasty including local kyphosis correction on pain relief

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ABSTRACT

Vertebral compression fractures (VCFs) are the most common complication of osteoporosis. Most of the times VCFs lead the patients to the health care system because of the severe pain and many of them require surgical approaches for pain relief. Percutaneous vertebroplasty (PVP) and balloon kyphoplasty (BK) represent two surgical procedures involving percutaneous injection of bone cement into a collapsed vertebra. The aim of these two techniques is to restore vertebral height and to provide pain relief. Percutaneous vertebroplasty may provide correction of the local kyphosis, however it does not seem to play an important role on pain relief. We reviewed reports of these two procedures in patients with osteoporosis. Most of the case reports suggested that an over 67% relief of patients symptoms, but there are also complications which are relative to these methods. Some of these complications include new VCFs in adjacent adjacent levels as well as pain due to cement extravasation.

Key Words: Vertebral fractures; Osteoporosis; Vertebroplasty; Kyphoplasty

Introduction

Osteoporosis is an epidemic of the modern world. It actually has an effect on 28 billion Americans and this number is expected to be increased through the next decades. Osteoporosis and its complications broke out as life expectancy has been extended. Vertebral Compression Fractures (VCFs) tend to be the most common complication of osteoporosis and they do happen with high frequency as 750,000 VCFs per year. Moreover, one third of the above fractures cause height loss, spinal deformity (kyphosis, scoliosis), acute and chronic pain, restriction of thoracic contents leading to respiratory complications, impaired mobility and disability. At the same time, 85% of symptomatic patients with acute VCF will settle with 12 weeks of conservative treatment. However, the remaining 15% of patients with chronic pain, not responding to conservative treatment, will seek surgical treatment. The main goal is to relieve pain and help the patients gain the loss of quality of their lives. It is generally accepted that wide surgical approaches and implants cause frequent failures and non-union due to low bone quality of elderly patients. As for the correction of the local kyphosis, the angular reduction sustained by kyphoplasty at the level of the VCF does not reflect to similar correction of the overall spinal sagitall alignment [1]. Over the last

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decades several minimally invasive techniques have gained popularity. Especially, vertebroplasty and kyphoplasty are two percutaneous procedures which improve the quality of life and offer pain relief to 67% of the patients [2].

The purpose of this study was to retrieve recent data on the treatment of chronic pain following VCFs with vertebroplasty and kyphoplasty and assess pain relief following vertebral height restoration. A PUBMED search was performed using the terms 'Vertebroplasty' and 'Kyphoplasty' to determine effectiveness on pain relief in patients with VCFs and to investigate its impact following local kyphosis correction. Only studies on patients with osteoporotic fractures were included.

Vertebroplasty is the percutaneous injection of PMMA into a fractured vertebral body through one or two bone biopsy needles. Percutaneous verterbroplasty (PVP) has been performed since the 1980. It was first used as a treatment of an aggressive hemangioma but soon later it was noticed that this operation is effective for painful vertebral compression fractures [3-5]. Today PVP is performed worldwide mostly for the treatment of painful osteoporotic vertebral compression fractures, and it is generally seen as a safe procedure providing pain relief and improving patient's physical and mental functions [4,5]. Kyphoplasty involves inserting bone tamp/balloon into the vertebra, under image guidance. When inflated with radiocontrast medium, the inflatable bone tamps compacts the cancellous bone and reexpands the body, thus the endplates are elevated without expending the fractured vertebral body laterally or posteriorly. To achieve an ''en masse'' reduction, usually two balloons are required. The expansion of the balloons offers local kyphosis correction. The cavity facilitates the placement of thick PMMA under low pressure, decreasing associated risks related to the deformity, filling control and vertebral stability, thus safely decreasing pain and improving mobility [6].

Patients with prolonged VFCs associated pain have been treated with this these percutaneous procedures. The best candidates appear to be patients with focal, intense, deep pain and evidence of a progressive VFC by conventional radiography and MRI. In most studies, patients were submitted to the percutaneous procedure when pain lasted several weeks following injury.

Discussion

During or soon after the procedure, X-ray or CT imaging is performed to evaluate the vertebral filling and exclude nerve roots and spinal cord compression. Following surgery, patients remain supine 1-2 hours to allow complete curing of the PMMA. From the first postoperative day and two weeks following treatment, pain relief was significantly improved compared to conservatively treated patients [7]. Winking et al. indicated that a total of 92% of patients who underwent percutaneous PMMA vertebroplasty reported an immediate pain relief that lasted for a minimum of one year after the procedure. Two weeks after treatment, pain relief was less significant and the reason was a new VCF in adjacent vertebral bodies [8].

Vormoolen et al [9] stated that the presence of bone marrow edema (BME) is an important radiologic criterion associated with pain. The same study mentions that 94% of patients with BME demonstrated pain relief during the first month and 97% the first trimester after the procedure. On the other hand, only 71% of those without BME showed pain decrease during the same periods. Therefore, it is clear that these percutaneous procedures offer a quicker pain relief in a higher percentage of patients with VCFs, than those who underwent conservative treatment. Pain reduction from initial visit to 3-month follow-up is comparable. Furthermore, new adjacent fractures are observed in the PVP groups and nearly none in the group of conservative treatment [4].

Conservative treatment and PV are both associated with significant improvement in pain and quality of life, in patients with VCFs over the first year [10]. Although patients treated with PVP show greater pain relief soon after treatment, they demonstrate a higher risk for a new VCF. PVP is a fair treatment for patients with sub-acute painful osteoporotic vertebral fractures; however the majority of fractures will heal after 8-12 weeks of conservative treatment with subsequent pain decline [3]. The risk of a new VCF in a level adjacent to a treated fracture exists and must be taken under consideration before the procedure. In addition, the new fractures occur nearly with the same frequen-

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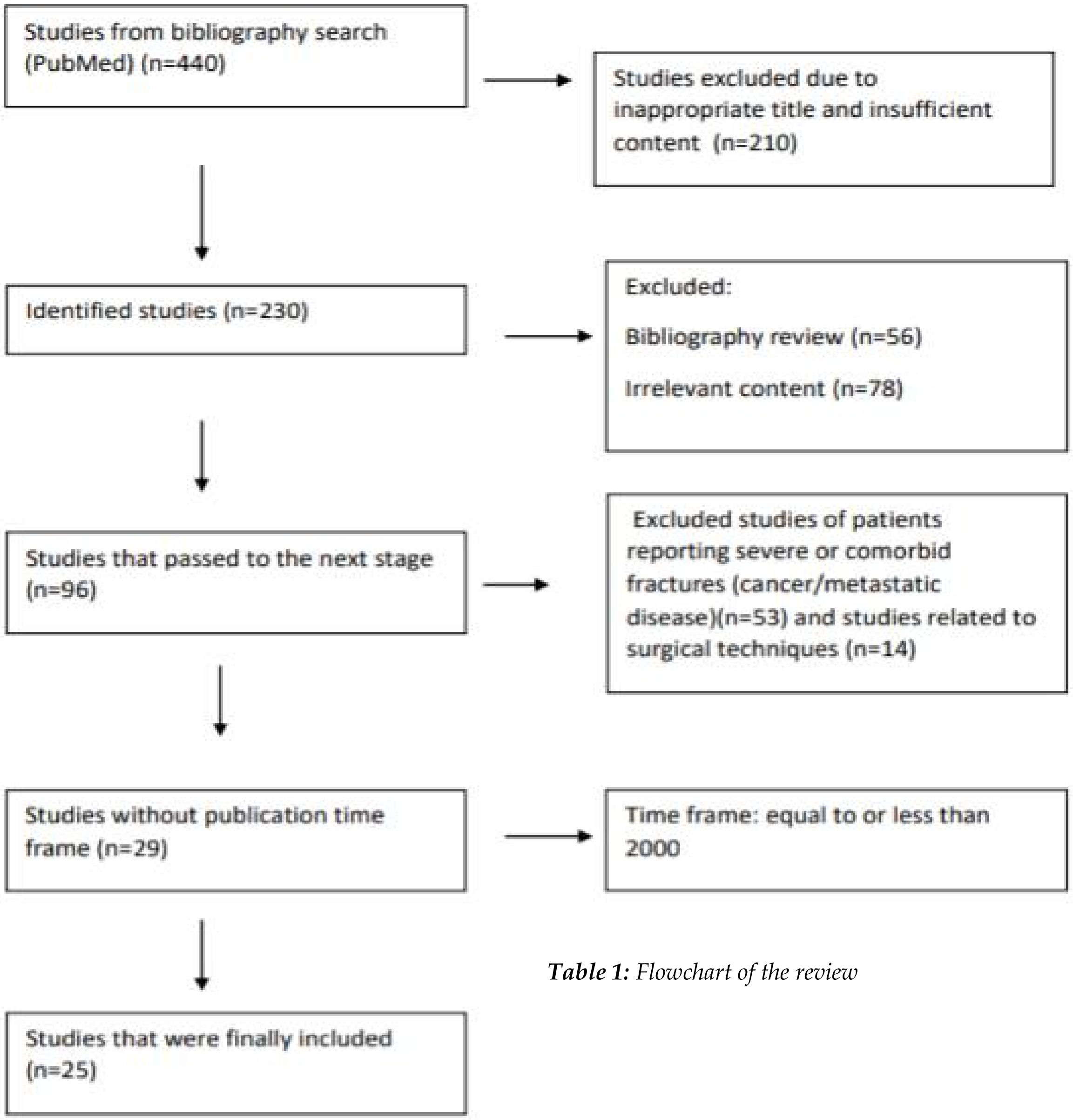

Table 1: *Flowchart of the review*

cy both in kyphoplasty and vertebroplasty.

It is generally accepted that the modified weight-bearing effects following kyphoplasty or vertebroplasty and the increased vertebral stiffness are the major factors for the development of new VCFs. Recent studies indicate that nearly 25% of patients treated with PVP develop one or more new VCFs in the first year follow-up. The majority of them suffers from a new VCF during the first three months, located at adjacent levels to the previous VCF [11]. Other studies with longer follow-up (48 months) report that 52% of the treated patients developed a new VCF. In general, 1/4 patients who underwent PVP will develop a new VCF in the following year. It must be mentioned that BK tends to have lower risk to cause an adjacent-level compression fracture because of the effective restoration of the overall spinal balance [12]. Despite the risk of new fractures, the benefit from VB/BK is greater because regaining painless mobility is a weapon to combat osteoporosis, as the lack of loads weakens BMD [13]. Evaluation for secondary causes of osteoporosis and treatment with appropriate phar-

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macologic agents for osteoporosis is particularly important for these patients. It must also be maintained that the volume of the PMMA does not seem to affect the risk of new VCF [2], however insufficient cement filling of the vertebral body may lead to unrelieved pain which will probably require reoperation [14].

As for the correction of the spinal deformity, it is more significant in patients with BK [15] but there is still no direct relationship found between local kyphosis correction and pain relief. Partial vertebral height restoration does not result in additional pain relief or improved quality of life [1]. Even in studies including patients with 8,8 degrees of correction, according to Cobb's technique, no significant difference was shown, compared to patients with no height restoration. Moreover, it must be considered that it is unrealistic to expect a 1 or 2 level kyphoplasty to improve significantly the overall sagittal alignment after VCFs. Of course, kyphoplasty is effective in partially reducing the angular deformity and regaining lost height of a VCF, however, the angular reduction at the level of the VCF does not translate to similar correction of the overall spinal sagittal alignment [16]. Furthermore, the volume of the inserted PMMA does not reduce kyphosis [17]. As far as for the inserted PMMA is concerned, although BK offers greater kyphosis correction, it is associated with lower rate of cement leakage. A very interesting finding in the case of height restoration of the fractured vertebrae is that an adjacent fracture in induced not due to elevated stiffness of the treated vertebra, but instead due to an anterior shift of the upper body [18].

In conclusion, both VB and BK are pain relief procedures. Vertebroplasty offers greater pain relief while kyphoplasty improves quality of life. It must be mentioned that both minimally invasive procedures improve functionally the patients to a greater degree than conservative treatment [19]. Especially for the elderly patients, vertebroplasty results in earlier hospital discharge and lower readmission rates [20]. Moreover, PVP and BK are related with a lower risk of re-fractures at the treated level, in contrast with non-surgical treatment. When compared directly, BK and PVP had the similar risks of re-fractures at the treated level [21]. As far as the correction of local kyphosis is concerned, despite the fact that vertebral height restoration can be achieved with vertebral augmentation procedures (especially with BK), there has never been shown to result in improved post-VCF clinical outcomes (improvement of the pain or mobility) or reduced post-VCF morbidity [22]. It must be clarified that the height restoration from BK does not seem to have an effect on fracture pain, however an improved spinal alignment is related to improved pulmonary mechanics, decreased pain associated with spinal deformity and reduced risk of an adjacent-level vertebral fracture [23]. Considering the radiological outcomes, although BK has the advantage on this section, still it does not seem to have any clinical relevance [24]. Concerning mortality, the latest data support that vertebral augmentation (more specifically BK slightly more than VB) lead to 22% reduction compared to conservative treatment [5]. Although these percutaneous procedures offer pain relief and improve quality of life, there are still several important questions concerning their mechanism and effectiveness that will need to be answered [25].

Conflicts of Interest

The authors declare no conflict of interest.

The authors declare that no funding has been received for this research.

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Management of neurogenic bowel dysfunction in patients with spinal cord injury

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ABSTRACT

The number of individuals vulnerable to bowel and bladder dysfunction is ever-increasing. Spinal cord injury (SCI), both traumatic and non-traumatic, has an estimated prevalence of over 2.5 million worldwide. Learning how to manage patients who exhibit such pathology is of the essence in order to ameliorate the patient's quality of life. This review strives to present the most important aspects of the management process. It is very important to examine all the aspects of the management process in order to have a more holistic view of the patient's needs. The key to a successful treatment is communication. By enhancing and supporting the exchange of information between doctors, care-givers, nurses and patients the management process is rendered easier for all parts involved.

Key Words: SCI, Neurogenic Bowel, Management

Introduction

The number of individuals vulnerable to bowel and bladder dysfunction is ever-increasing. Spinal cord injury (SCI), both traumatic and non-traumatic, has an estimated prevalence of over 2.5 million worldwide. Amongst those suffering from central nervous system injury or disease, bowel symptoms are experienced commonly. Of those with SCI, up to 95% report constipation and 75% have experienced episodes of fecal incontinence.

The symptoms of NBD have a substantial negative impact on quality of life, social integration, and personal independence. Only 6% of SCI patients require no intervention to support their bowel function. As many as 65% need to employ intrusive options such as digital stimulation or evacuation of the anorectum, and one-third require assistance with bowel care [1] .

For all the reasons mentioned above, the author deems that a review of the current literature concerning NBD is of great importance, since it is a matter that requires clinical (doctoral and psychological), nursing and even surgical interventions (in some cases). Learn-

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ing how to manage patients who exhibit such pathology is of the essence in order to ameliorate the patient's quality of life. This review strives to present the most important aspects of the management process.

Discussion

The Neurogenic Bowel

Following spinal cord injury, neurogenic bowel dysfunction (NBD) is defined as a colonic dysfunction due to a lack of central control based on an upper motoneuron (UMN) or lower motoneuron (LMN) lesion with reflexive or areflexive bowel, respectively. It constitutes a major physical and psychological problem in individuals with spinal cord injury (SCI) with a high impact on quality of life and restriction of social activities [2].

Patients with sensorimotor complete SCI, classified by the American Spinal Injury Association Impairment Scale (AIS) as AIS-grade A (AIS-A), lose the sensation of rectal filling, anal sensibility, and the ability to evacuate their bowels, resulting in impaired defecation [3]. The improvement of bowel function is considered amongst the highest priorities in spinal cord injury patients. All patients with complete SCI suffer from bowel-related symptoms and the frequency of gastrointestinal problems increases in individuals who had been spinal cord injured for more than 5 years.

The Bowel Management Program

To prevent such gastrointestinal complications, a specific bowel management program during rehabilitation is required to achieve efficient, effective, and consistent stool evacuation to avoid chronic overdistension of the colon. Whereas normal individuals have synergistic activity between rectal smooth muscle and pelvic striated muscles, it is hypothesized that SCI patients have dyssynergic pelvic floor movements, contributing to outlet obstruction [4].

This constitutes one of the key factors interfering with regular bowel function. Sphincter electromyography findings indicate involuntary external as well as internal

anal sphincter activity supporting the notion that outlet obstruction may be due to persistent external anal sphincter contractions (although results of anorectal manometry did not reveal a clear correlation with clinical bowel dysfunction). Overall, the exact pathophysiological process of outlet obstruction involving the pelvic floor and anorectum of SCI patients has yet to be examined.

Management

In 22% of individuals with SCI, bowel management takes up to an hour on every occasion, and in 14%, it takes over 60 minutes [5]. The consequences of all this are loss of independence and dignity, embarrassment, anxiety, depression, social isolation, and loss of sexual activity [6]. In fact, the burden of NBD is so great that SCI patients report bowel dysfunction as more problematic than any bladder dysfunction, sexual dysfunction, pain, fatigue, or perception of body image.

While urological sequelae and their treatment are well documented, neurogenic bowel dysfunction (NBD) is among the least discussed topics in the literature, perhaps because of the misperception that there is little serious morbidity or mortality associated with NBD [7].

Management of NBD has often involved diet, mild laxatives combined with sporadic enemas, or digital maneuvers. In most patients, regular conservative bowel management is not effective, and during the last decade, several new therapeutic modalities were suggested: prokinetic agents, biofeedback, enema continence catheter, the Malone antegrade continence enema administered through an appendicectomy and sacral nerve stimulation.

To date, there is limited literature evidence supporting any bowel management program for NBD. However, a recent randomized controlled trial found that patients treated with the Peristeen Anal Irrigation System (Coloplast A/S, Kokkedal, Denmark) had fewer complaints of constipation, less fecal incontinence, improved symptom-related quality of life, and reduced time consumption on bowel management procedures, compared with patients treated by conservative bowel management technics.

Malone antegrade continence enemas are used in the management of neurogenic bowel to prevent fecal continence. Several different irrigation solutions have been described but glycerin, an osmotic laxative that promotes peristalsis, has rarely been mentioned or studied. Chu et al assessed clinical outcomes in

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patients with a Malone antegrade continence enema using glycerin-based irrigation [8]. Of the 23 patients with follow-up greater than 6 months, 19 used glycerin-based irrigation. The average age at surgery was 8.8 years. Patients using glycerin instilled a median of 30 ml (mean 29) glycerin and 50 ml (131) tap water.

The fecal continence rate was 95% and stoma leakage rate was 16% and only 16% of patients required daily irrigation.

Glycerin is a viable and effective alternative irrigant for antegrade enemas of neurogenic bowel, with an excellent fecal continence rate. The volume of irrigant needed is typically less than 90 ml, which is much less than in published reports using tap water alone.

The Aspect of Nursing

Nursing is recognized as the main branch of the interdisciplinary team, which provides nursing rehabilitation for people with Spinal Cord Injury.

Rehabilitation Nurses perform many types of interventions, including in-patient care, patient and caregiver education, care management, and psychosocial support for patients and their families. Nursing interventions have perhaps the most significant impact in the areas of functional independence, social reintegration, and quality of life in the long run.

On the part of patients and their families, the areas of greatest interest to them, according to a study, include motor function, bowel and urination control, sexual function, and pain management. Patients require comprehensive care and assistance, so time should be properly planned to accommodate a range of activities. Nurses should develop a therapeutic relationship that will provide a better understanding of their role by the patient.

Through in-patient education programs, the person with Spinal Cord Injury learns to understand and monitor their own physical, emotional and social well-being. Improvements in knowledge do not necessarily translate into problem-solving ability, even for important issues. This may indicate the need to incorporate more active lifelong learning strategies or training programs to facilitate knowledge transfer through life situations).

Several studies show that the degree of active involvement of the patient in rehabilitation has a positive correlation with the improvement of functional capacity and outcome, which is why it is preferred in every treatment model.

An individualized rehabilitation program reflects the needs and expectations of people with Spinal Cord Injury as part of their family and professional life, intending to return to the community. Rehabilitation Unit staff needs to understand how patients experience rehabilitation and the process of adapting to the new situation.

Rehabilitation Nurses devote significant time to patient education and psychosocial support and empowerment for themselves and their families. Usually, this is not included in traditional documentation systems. Quantifying these interventions will allow researchers to discern if there is a correlation between time spent on training activities and patient outcomes. Additionally, professionals working in Rehabilitation centers should utilize patients' expectations, desires, and experiences to develop better Rehabilitation programs [9].

Examining Mortality

A history of chronic pressure ulcers, amputations, depressive disorders, symptoms of infections hospitalization within the past year were all predictive of mortality. LE estimates were generated using the example of a man with a non-cervical, non-ambulatory SCI. Using 3 age examples (20, 40, 60y), the greatest estimated lost LE was associated with chronic pressure ulcers (50.3%), followed by amputations (35.4%), 1 or more recent hospitalizations (18.5%), and the diagnosis of probable major depression (18%). Symptoms of infections were associated with a 6.7% reduction in LE for a 1 SD increase in infectious symptoms [10].

Clinical Implications

As expressed by Krause, there are many ways the current findings can be translated into clinical practices. The identification of the predictors will allow clinicians from multiple disciplines to assess risk for mortality quickly and efficiently. A minimum intervention for any clinician is to share information with the individual who has an SCI. Clinicians may use the information on the specific risk factors to develop interventions in their own area of expertise. For instance, rehabilitation psychologists should ensure assessments for

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depression on outpatient visits and those at high risk for depression should be identified and appropriate follow-up should be implemented. Reviewing the history of infections on outpatient visits is also important. Other types of assessment, such as skin integrity, are almost considered to be a matter of routine. Interventions need to be developed targeting stakeholders more directly by disseminating information to them, which may be used to promote self-health. Those with SCI certainly know chronic Pus (pressure ulcers) lead to declining health, but knowing the extent to which they result in diminished Life Expectancy may be more likely to lead to changes in health behaviors [11].

Communication is key

Communication is all about trust. The patient demands to be treated as an equal and will not trust his/hers health-workers completely, until said trust is established. Clinicians have to understand that achieving and creating an effective communication regime takes time. But making the patient feel comfortable with his condition and his/her helpers is of the essence. Subjects such as NBD usually are a taboo issue, even through the scope of confidentiality between a doctor and his/her patient. The people responsible for the management of NBD should work in the context of the notion of emancipation. The person needs to be reminded that he/she can still be a productive individual.

Conflict of Interest

The author declares no conflict of interest

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Physiotherapy rehabilitation of respiratory system and the factors which facilitate its plasticity after Spinal Cord Injury

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ABSTRACT

Spinal cord injury (SCI) is quite common and can occur either as an acute injury after an accident or a fall, or as the result of other pathological conditions. SCI results in important loss of functionality, which apart from the kinetic affects multiple physiological systems, such as the respiratory system. The aim of this study was to review the methods of respiratory physiotherapy rehabilitation in patients with SCI. For this reason, a review of the current literature was performed by using the online PUBMED database and the following keywords: spinal cord injury; respiratory physiotherapy; respiratory muscle training. Inclusion criteria in the review were: primary studies in humans with SCI, published after 2000 in English language. Twenty-one studies were finally included in the review. Currently, many respiratory physiotherapy protocols are available aiming at the strengthening of respiratory and abdominal muscles, respiration training and phrenic nerve stimulation. The respiratory and abdominal muscles strengthening interventions improve respiratory function and cough production capacity and decrease the frequency of respiratory infections. Phrenic nerve stimulation constitutes a promising technique, as it promotes cough production, decreases respiratory infections and is more cost- effective compared with other respiratory physiotherapy interventions.

Key Words: spinal cord injury, respiratory physiotherapy, respiratory muscle training

Introduction

Spinal Cord Injury (SCI) is a severe type of trauma of the central nervous system, which continues to be a global concern. It significantly affects patients' quality of life and increases the burden at the social care systems. In addition, it prevents social accession, causes physical impairment and malfunction of several body organs, but more importantly increases mortality [1], [4]. The prevalence rate of SCI is 20.7-83 per million in the USA and approximately 8.0-130.6 per million in Europe. Many studies have shown similar frequency in China [1].

The pathophysiology of SCI can be divided in two stages: primary and secondary injury. The primary injury is caused by immediate damage to the nerve tissue from the main mechanical attack. The secondary injury is caused by a series of events, such as bleeding, edema, demyelination and inflammatory reactions [15].

In case of SCI due to an accident or a fall, a significant percentage of patients die instantaneously or within a few days after the injury. More than half of the SCI patients will have to be treated for associated injuries during their initial hospitalization, such as traumatic brain and cerebrovascular injury. In their future life, patients who survive the primary injury will face several risks related to post-injury medical complications. The overwhelming consequences of SCI were considered, until very recently, non reversible. Before the appearance of improvements in the acute clinical management in the middle of 20th century, the expectation of life of SCI patients was low. Nowadays, patients with SCI are successfully reintegrated in the society, and to a great extent, people with incomplete damage can live independently, having almost a normal life. However, the absence of functional improvement can increase the rate of serious complications, such as respiratory failure. [24] Respiratory muscle weakness after SCI has negative consequences for the patient, by affecting ventilation and pulmonary volumes. Furthermore, the inefficiency of the expiratory muscles, leads to incomplete achievement of cough and secretion explement. Therefore, there is a high possibility of respiratory morbidity with continuous respiratory infections (2/year/person) often leading to pneumonia. [6] [22]. Indeed, respiratory dysfunction complications as atelectasis and pneumonia keep on being among the main death causes in patients with complete SCI [27], [2]. Respiratory failure can partly be treated with mechanical respiratory support, however, making the patient more prone to pneumonia and atelectasis. Because of these complications, the research of therapies and strategies for functional improvement of respiratory function after SCI is of major importance [34]. Respiratory muscle training includes special training of the inspiratory and expiratory muscles to improve strength and resistance. Respiratory muscles can be trained in a similar way as the extremity muscles with devices that increase the muscle load. A respiratory physiotherapy session contains a specific number of repetitive exercises or a specific time-period for each exercise. The intensity is defined individually as a percentage of the maximum measured respiratory strength and the respiratory pressure or capacity [13].

Although the advantages of physiotherapy in patients with SCI are well known, there is currently no literature review providing collective information about the several used techniques and their efficacy. The aim of this study was to review the methods of respiratory physiotherapy rehabilitation in patients with SCI.

A review of the current literature was performed by using the online PUBMED database and the following keywords: spinal cord injury; respiratory physiotherapy; respiratory muscle training. Inclusion criteria in the review were: primary studies in humans with SCI, published after 2000 in English language. Initial search resulted in 56 articles. After checking titles and abstracts, 23 articles were rejected for not meeting the inclusion criteria. More specifically, the studies were rejected because of their irrelevant title and because the examined population was animals or people without SCI. Of the 33 remaining publications, 6 were rejected because respiratory physiotherapy was not the main intervention. Finally, there were 27 studies included in the present review (Table 1).

Discussion

Respiratory muscles strengthening

Respiratory muscles are skeletal muscles. Training can increase the strength of the muscles involved in inspiration and expiration, improving the pulmonary function. In case of complete muscle paralysis, training cannot improve muscle function. However, in patients with incomplete SCI, training could reinforce the activation and the coordination of the respiratory muscles. Nowadays, there are several respiratory muscle training (RMT) techniques for patients with quadriplegia to enhance and improve their endurance. These techniques include resistance breathing, endurance loading devices, flow spirometry, positive expiratory flow devices, lingual-pharyngeal respiration and singing. RMT in patients with quadriplegia has proven to be beneficial for the respiratory function and resistance and patients’ perceived difficulty to breathe. In a recent study, one year after RMT, 84% of patients who were

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included in the study improved in terms of strength and breathing and reported to have more air in their lungs [3]. Furthermore, in another study, patients who did not receive RMT had three times higher incidence of mortality compared to the intervention group [18]. Similar results have been reported with respiratory physiotherapy application in patients with incomplete quadriplegia or complete hemiplegia. [25] Moreover, RMT leads to significant improvement of the spirometric values, the VO_2max, the time until fatigue and the maximum output [29]. It has been reported, that 1000 repetitions of Inspiratory Muscle Strenght Training (IMST) can lead to 1% increase of maximum inspiratory pressure ($PI_{max)}$, during a high intensity training (above 80-85% of peak oxygen uptake). Also, an increase of 10 units in training intensity can lead to a 7% increase of the maximum expiratory pressure ($PE_{max)}$ in patients with complete motor lesions [27].

The improvement of cough strength is also a factor that minimizes the risk of respiratory complications. To achieve an adequate cough a person needs not only an increased forced expiratory activity, but also an increased pre-cough inspiration. Muscle strength is highly related with cough capacity [26]. It has been found that the Respiratory Resistance Training (RRT) flow devices can enhance the lung function and performance in patients with SCI. A concurrent flow resistance device can increase the maximum inspiratory pressure (MIP) which is highly related to diaphragm strength. After training, there is an activation of phrenic motor neurons in patients with weak diaphragm. In a recent study, the MIP in the group of patients that received therapy was 33cm H_2O higher compared to the control group [19]. The singing intervention is also beneficial for patients with SCI who have vocal restriction. It has been observed, that singing intervention activates laryngeal muscle [30].

Abdominal muscle training

In addition to the respiratory muscles, the abdominal muscles play an equally important role in the respiratory function. Consequently, patients with SCI that have weak diaphragm, abdominal and intercostal lateral muscles, have a poor pulmonary function. Therefore, stimulation and strengthening of the abdominal muscles is a basic goal of respiratory physiotherapy. A combination of exercises for the abdominal and the respiratory muscles could have major effects in pulmonary function. Patients that performed the abdominal drawing-in maneuver using a stabilizer and RMT using a spirometer showed 19,98% higher Forced Vital Capacity (FVC) and 16,71% higher Forced Expiratory Volume in one second (FEV_1) [16]. In fact, abdominal muscles training can lead to a faster weaning from the mechanical ventilation. In a recent study, patients submitted to abdominal muscles training were able to wean from mechanical ventilation 11 days earlier, compared to patients who didn't perform abdominal muscles training [21]. Studies have shown that the application of an abdominal binder in patients with acute complete quadriplegia can improve their respiratory and vocal function and their blood pressure. The binding of the paralyzed abdomen can significantly improve the FVC, the FEV_1, the maximum expiratory flow, the maximum inspiratory pressure, and the maximum phonation time [33].

As mentioned before, cough is a significant parameter of the normal respiratory function. Functional electrical stimulation (FES) with electrodes placed in a posterolateral position over the abdominal wall is a very promising technique that improves cough. Thus, cough training in addition with FES can increase the voluntary cough pressures in patients with SCI (especially those with high level injuries). In a recent study, patients submitted to this treatment showed a 50% increase in the PEF rates [20]. In addition, a device called sniff controller can be used to self- trigger the abdominal FES to enhance cough. Patients using this device showed a higher peak flow which is the first event of the cough process. Moreover, the Peak Expiratory Flow (PEF) of automatic Sniff Controller-FES assisted cough increased about 23-27%. Furthermore, 30% of the patients maintained the abdominal muscle strength after the cough effort. All assistive methods improved cough efficacy compared to unassisted cough by about 25% and reached 76% of the mean expected values of PEF [13].

Breath training

Breath training exercises include specific techniques of breathing such as hyperpnoea, intermittent positive pressure breathing and intermittent hypoxia.

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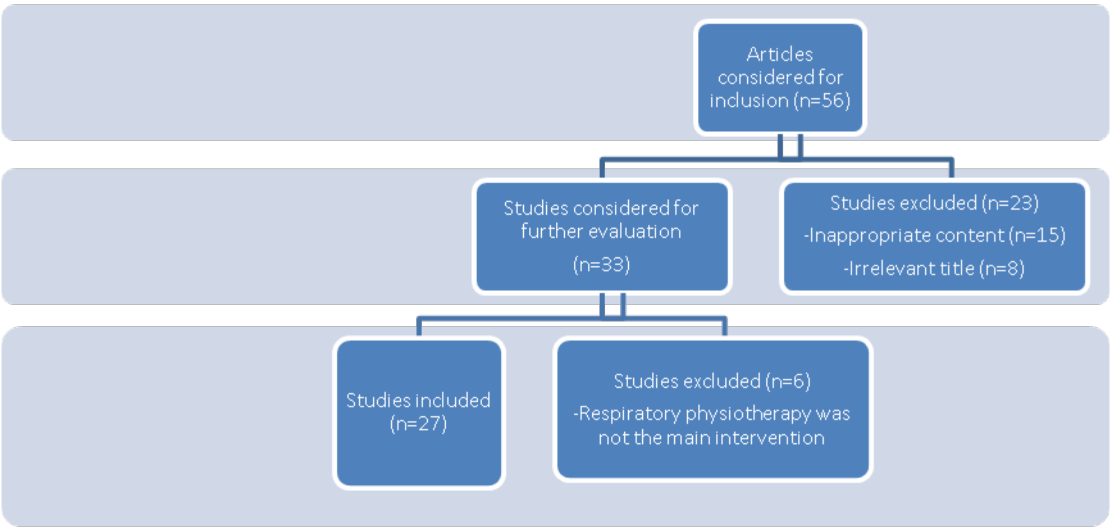

Table 1: *Current review flowchart.*

Normocapnic hyperpnoea using a laboratory-developed device can improve the endurance of respiratory muscles. In a recent study, after a muscle endurance training program with normocapnic hyperpnoea, patients showed a difference about -20% in Borg Scale [32]. It has been proven that forced hyperpnoea is beneficial for RMT, as these muscles usually work at law resistance [35]. There are also similar devices that contribute to the expiratory muscle resistive training with maximal expiratory force. A small handheld device is used to make repeated expiratory resistance breathing exercises to improve the measures of ventilator function in patients with SCI [28].

Electrical nerve stimulation

Electrical nerve stimulation techniques are widely used for skeletal muscle function rehabilitation in several kinetic systems, in patients with SCI. For more than five decades, this technique is also used for the rehabilitation of the respiratory muscles [5], [11]. In phrenic nerve stimulation the electrodes are placed in the thoracic wall of the patient. In a recent study, the authors reported that by using this technique patients avoided the need of mechanical ventilation [14]. The intramuscular placement of phrenic nerve electrodes instead of the conventional phrenic nerve pacing reduces the risk of phrenic nerve injury [7]. The use of a Spinal Cord Stimulation (SCS) system implanted in the lower thoracic spine of patients with SCI can successfully enhance cough, while it increases the airway pressures and high peak airflow rates. It is more beneficial when the patients try the glossopharyngeal breathing and then perform cough. Another type of functional electrical stimulation is the intramuscular diaphragm pacing system which also enhances the respiratory muscle function [8], [9].

In conclusion, respiratory physiotherapy in patients with SCI can be especially helpful in improving breathing and cough, preventing infections, and improving patients' overall quality of life. Respiratory physiotherapy has a wide scientific field and several interventions that should be applied individually according to patient needs.

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Pressure sores as a complication in patients with spinal cord injury. Prevention and treatment

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ABSTRACT

The present study critically examined pressure sores/ulcers as a seminal side effect associated with patients who have suffered spinal cord injury. The statistics show that a large percentage of this patient group develops pressure sores due to prolonged bedrest and inactivity. The aim of this study was to present a review of pressure sores treatment tactics that specifically pertain to patients who remain immobile due to spinal cord injury. The available methods for prevention and treatment of pressure sores either conservatively or surgically were assessed. Source material for this review was chosen according to its specificity to pressure ulcers and spinal cord injury. The choice of treatment is decided according to the categorization of pressure sores into 4 stages. The study focused on surgical treatment via the use of flaps, that has been shown to be revolutionary in handling advanced pressure ulcers (stage III and IV), yielding a large percentage of successful operations. The surgical intervention was then extensively analysed in terms of operative procedure, postoperative management andpossible complications. In conclusion, flap reconstruction was found to be successful in optimizing the treatment of pressure ulcers in patients with spinal cord injury.

Key Words: Pressure Sores, Spinal Cord Injury, FlapReconstruction, Pressure Sores'Treatment

Introduction

Patients suffering from spinal cord injury (SCI) represent a population susceptible topressure ulcers/sores. The prevalence of pressure ulcers is highly variable and seems to be pertinent to the degree of spinal lesion. According to a recent literature review, 47.7% of patients with paraplegia and 33.9% of patients with quadriplegia are reported to suffer from pressure ulcers (1,2). Pressure sores usually form in, but are not limited to, the ischium, the femoral trochanter, the sacrum, and the heel (3,4). In quadriplegia, the most common site is the ischial tuberosity, representing 28% of all cases. Different categorizations of pressure ulcers have been reported over the years; however, the one that prevailed and is widely applied nowadays is the NICE. According to the latest parameters from 2015, four categories of pressure ulcers have been identified. Each category (stage) dictates the method of appropriate treatment for a given case (7). Category I includes lesions with intact skin and redness which does not

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blanch. Category II includes lesions with partial loss of skin's layers or blister filled with clear fluid. Category III includes lesions with total loss of skin thickness, whereby the muscle and bone are not visible. Category IV includes lesions with total loss of tissue thickness, whereby the muscle and bone are visible (7).The current strategy for preventing and treating pressure sores consists of three main factors: the evaluation of a patient's risk for developing an ulcer, the adaptation of an adequate prevention scheme for patients in high risk for ulcer development and ultimately, the ulcer treatment (8).

The purpose of this study was to present a review on pressure sores' management in patients with SCI. Specific emphasis was placed on the surgical approach with flap reconstruction that has been shown to optimize the recovery of these patients and ultimately improve their quality of life. Research was conducted using Google Scholar online database to identify material that was relative to the specific group of patients suffering from SCI and developing pressure sores, as a result. Articles that were chosen were specifically assessed for their recency, for the review to be up to date with the latest standards of available treatment. In contrast, articles that were rejected included: studies still undergoing the experimental phase, studies often employing a very limited sample of participants and studies that yielded questionable results pertaining to the surgical treatment of pressure sores. Unsubstantiated sources of this type would otherwise compromise the focus of this study to identify the most effective available treatment (Table 1).

Discussion

1. Prevention of Pressure Sores

The basic prevention measures include the adjustment of pressure on the patient's skin and the use of specialized equipment (e.g. Alternating pressure mattress), as well as therapeutic interventions focusing on the application of bandages and the acquisition of a balanced diet rich in protein, iron, vitamin C and zinc. (8) Treating any condition which contributes to sore development such as diabetes mellitus and hypoalbuminemia, is also of vital importance. According to the suggestions of NPUAP, EPUAP, PPPIA, it is ultimately important to educate the patients and their families on managing pain and infection (9). The acronym, «SSKIN» represents the five steps in the prevention of pressure sores in patients with SCI. Each letter in the acronym stands for the words: **S**urface, **S**kin inspection, **K**eep moving, **I**ncontinence/moisture, **N**utrition and hydration. Specifically, healthcare providers but also family members should inspect patient's skin, as well as regularly move patients to avoid constant pressure in specific areas. Moreover, the patient must be inspected for incontinence and general moisture to the prone areas of the body so that the skin is being kept dry and clean. Lastly, the patient needs to receive healthy nutrition and adequate hydration. Another seminal prevention measure is the "five pillow rule" that employs the use of pillows to support patients' body. Pillow 1 is placed under the feet to elevate the heel. Pillows 2and 3 are placed between the ankles and the knees respectively, if the patient is lying sideways. Pillow 4 is placed behind the back and pillow 5 under the head (10).

2. Treatment of Pressure Sores

The categorization of pressure sores has constituted a valuable tool in deciding the appropriate treatment for a given case. The treatment of pressure ulcers according to the respective category is an issue that has repeatedly occupied the medical community. According to the international guidelines, for categories I and II the conservative approach is suggested while the surgical approach is preferred for categories III and IV. In the case of the conservative approach, the process begins with the use of a bandage which fosters a humid environment appropriate for healing along with an antimicrobial bandage. Specialized bandages must have the following properties: (i) maintaining a sterile content, (ii) provide thermal insulation, (iii) guard against bacteria and infection, (iv) provide water absorbency, (v) protect against skin damage after removal and (vi) ensure patient's comfort when the dressing is changed (8). Hyperbaric oxygen therapy and electrotherapy are also used. The use of nutritional supplements for patients who suffer from nutritional deficits is recommended. The use of systematic antibiotics is not required, except from cases where infection is proven by tissue cultures. Antibiotics are initially provided empirically and are then de-escalated according to the antibiogram. The infection of an ulcer can amount to inflammation of the soft tissues or bone, cellulites, formation of abscess, bursitis and osteomyelitis of the bone near the trauma (11). Pressure sores are also a common cause of bacteraemia in patients with SCI (12). Ulcer cultures most commonly grow mixed flora (23.5%), followed by Enterococcus sp. (20%), no growth (19.1%), and Pseudomonas aeruginosa (11.3%) (13).

Applying monitored degrees of negative pressure has been proven beneficial for various kinds of trauma, as it can speed-up recovery time by boosting wound healing. Negative pressure levels are shown to be most effective at 125mmHg below ambient pressure, especially when applied in a circular way for five and two-minute intervals. The use of negative pressure is shown to eliminate the interstitial fluid, lessen localized edema and improve blood flow, resulting in the decrease of bacterial numbers in the infected areas. Vacuum-Assisted Closure (VAC) is an effective device that utilizes the benefits of negative pressure to prepare trauma for surgery by accelerating healing, thus significantly reducing the chances of complications as well as prospective hospitalization time (14,15). VAC is also shown to be successful in the treatment of non-healing wounds that would otherwise remain open (primary healing) (16,17). In general, the conservative treatment of ulcers is long lasting, requires the use of specialized methods and generates large hospitalization costs that add a great economic burden to the health care system.

The conservative approach is ineffective when it comes to ulcer stages III and IV, thus the intervention of plastic surgeons for the creation of coverage with a tissue flap is deemed necessary (3,18). Surgical reconstruction combined with rehabilitation and training of the patient and his/her family reduces the chances for postoperative reoccurrence of the pressure sore (3). The choice of flap type depends on the affected site, the size of the ulcer and any past surgeries on the patient in the same area (16-21). For the surgical treatment of pressure ulcers, there are two available approaches: the one-stage reconstruction and the two-stage reconstruction. One stage reconstruction consists of surgical debridement and flap reconstruction in one procedure. Two-stage reconstruction includes debridement and final reconstruction performed in two different operations, with a six-week interval (22). Studies do not indicate any major statistical difference in the number of recurrent pressure ulcers or other surgical complications in SCI patients, who were submitted to reconstruction surgery in one or two stages. Thus, the decision of approach lies on the surgeons and the means available to them (23).

Flaps used for ischium pressure ulcer reconstruction should have good vascularity to ensure survival, to facilitate the control of infection and to provide adequate size and volume to eliminate empty space (27). Ischial pressure ulcers are usually observed in paraplegic patients using a wheelchair, where tissue pressure amounts to 80-100 mmHg based on the anatomical position. (28) The vicinity of the ischium with the perineal area makes the area prone to infection from faeces or urine, leading to skin disruption and enduring infection (29,30). Chronic infection of the site causes osteomyelitis of the ischial tuberosity and/or ischial bursitis, accompanied by necrosis of soft tissue (31). The coverage of deep and superficial areas of the deficit by separate flaps has the advantage of reconstructing the soft tissue deficit in the exact position that is anticipated, and the double flap technique allows for the reconstruction of soft tissue layer by layer, granting the advantages of each flap (32,33).

Trochanteric ulcers may be difficult to handle, particularly in cases of heavy bone engagement that demands a wide surgical debridement. The lingering wound is deep and substantially large thus, reconstruction must guarantee a total fill of all the dead spaces. Ultimately it must be covered with enough tissue to optimize healing and decrease the chance of recurrence. In SCI patients who develop trochanteric ulcers, muscle or cutaneous flaps are the ideal choice because the use of sufficient, viable volume is allowed. In such cases, the flap can be combined to achieve an optimal result. Trochanteric pressure ulcers are usually associated with osteomyelitis. Thus, surgical debridement should be extensive to remove all infected or non-viable soft and bony tissue. The gold standard is Gilderstone arthroplasty (30). Rectus femoris, vastus lateralis, and gracilis are muscles with nearby pedicles, easy to use as musculocutaneous flaps using a large skin paddle. The dissection of each flap is made through a single incision on the thigh and the donor site is then easily sealed by direct suture. The arc of rotation allows the flap to reach the deep surface of the deficit without extension. The combination of a muscle flap which is placed deeply and is covered by a musculocutaneous flap allows for full coverage of the deficit and its surface. In case of a single muscle flap, the surface is covered with a skin paddle, or skin graft (1).

For a long time, reconstruction of soft tissues around the area of the heel has posed a challenge for reconstructive surgeons. Reconstructive surgery in patients who also suffer from SCI exacerbates this problem. Due to prolonged immobility, the skin and soft tissues usually atrophy, especially in the limbs. Over the lateral malleolus, the primary closure is usually impossible due to bony prominence and the lack of available mobile and healthy local skin. Local skin flaps (rotation, transposition and advancement) are associated with similar problems. Skin grafts are usually set to fail as a result of direct exposure to bone, tendons and ligaments. The transposition of a microsurgical free flap is efficient and may address many of the limitations which are associated with various local and distal choices. However, this is a demanding and time-consuming technique that may also not be appropriate for certain patients (26).

3. Preoperative and postoperative management

Analysis of pressure sores includes deficit evaluation in relation to site, scale and depth. When the deficit involves an important percentage of the skin's surface, reconstructive options may be limited to skin grafts for extensive coverage or expansion of successive tissue. The components of a deficit may include one or all of the following: skin, nerves, mucosa, fascia, subcutaneous tissue, joint cartilage, muscle, bone and vessels. Each section affects the function and form on the site of the deficit. The choice of the appropriate reconstruction method is based on viability and relevant importance of replacing each section of the deficit. Ulcer analysis must also include the vascular status and the presence of infection in the exposed structures. Evaluation of the vascular status can be achieved with non-invasive means, such as Doppler ultrasound and Magnetic resonance angiography, or by invasive means such as angiography (25). The design of the flap is of vital importance. The finalized flap design is intended for stable transposition, gradual expansion or microvascular transplantation and must be based on the deficit's actual size. The initial design of the flap has an effect on future procedures, if the deficit recurs or demands review. In general, the making of the flap is delayed until sufficient surgical debridement is conducted. If simultaneous elevation and dissection occurs, the design of the flap must be fitting the maximum expected scale of the deficit. Identifying high risk patients is also significant. Smoking, obesity, cardiovascular diseases (hypertension, peripheral vascular disease), immunosuppression and pulmonary diseases are important factors that must be taken into consideration. These crucial factors will determine the selection of suitable patients and the selection of the right type of flap, as well as the success and longevity of the final result.

The patient should be positioned in such a way so as both donor and recipient sites are visible. If correct positioning cannot be achieved, then the placement of the patient must provide maximum visibility of the recipient site at least, especially if the required dissection is large (25).

Postoperative management of the flap is equally significant for the success of the operation, as the reconstruction itself. Maintaining appropriate position, temporary immobility and proper bandaging of the surgical wound are crucial factors that can promote a successful result. Pressure on the flap's base must be avoided during the postoperative period. When possible, the operated body part should be kept raised to avoid contact with any surface. If the site of the flap does not have protective sensibility, it should be placed in independent position. The use of a specialized bed with air mattress can be helpful in avoiding pressure of the dependent areas in patients with SCI (26). Restrictive bandages must be avoided, mostly around the area of the flap's base, where pressure in vascular stem may compromise the flap's circulation. The flap must be monitored for any circulation problems during the early postoperative period. Excessive movement in the flap site should be avoided by filling the areas adjacent to the nested site of the flap. Circular plasters must be avoided due to the threat of pressure that could result in postoperative edema and difficulty

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in monitoring the flap's blood flow.

In general, a closed drainage system is applied on the donor and recipient sites after closing. The drains are not removed until the patient is mobilized, since immobility can result in increased risk for oedema and subsequent seroma. Drains in close proximity to the tissue expander or the prosthetic implants must be removed as soon as possible to avoid the risk of infection. When the drained fluids are reduced to 20 mL in a 24hour period, the drain system can be removed. If possible, the drainage systems are removed after the 10th postoperative day to avoid possible infection of the wound during the removal of the system (25). Intraoperative antibiotics are recommended when the flaps are placed in pressure sores whose cultures were positive. Cultures of the area of the deficit can determine the necessity for postoperative treatment with antibiotics. The continuous use of postoperative antibiotics must be in accordance with the results of the wound's cultures.

4. Complications

Reconstruction with muscle and musculocutaneous flaps has repeatedly been praised for its safety and reliability. Its success has now led surgeons to opt for more complicated procedures, especially since they can preserve and enhance function and form. However, like all procedures these too can result in complications. Complications regarding the use of muscle and musculocutaneous flaps are due to mistakes that fall into three categories: judgement, technique and patient management. Frequent complications comprise seroma, hematoma, superficial skin necrosis, wound separation, insufficient coverage of the deficit, infection and partial or total loss of the flap. By assessing these complications in relation to the three categories, the surgeon should be able to comprehend the cause of a given complication to prevent future problems (26). Failure of the surgeon to judge correctly often stems from inadequate preparation, inappropriate design of the flap or insufficient knowledge of anatomy. The surgical technique directly impacts the result of any procedure. Tissue manipulation, specifically of vascular pedicles, is of major importance for the flap's success. Vessels can be compromised in any stage of the surgery and are subject to spasms, shear, and twist. In order to avoid that, the surgeon can place temporary sutures between the flap's skin and the muscle or the fascia beneath it, to prevent tearing of the perforating vessels. Avoiding Eschewing skeletonization of the vascular pedicle if not required, is also critical to avoid spasms and injury (26). Ultimate flap loss may be ensued by intrinsic or extrinsic factors. Intrinsic factors mainly refer to insufficient blood supply, which is the main reason for the flap to be jeopardized. Extrinsic factors may involve infection, hypotension, and vasoconstricting agents. Moreover, hematoma could compromise the flap by generating compression or tension. Surgical review of the flap must be prompt when failure is suspected. Complications relating to the donor site comprise fluid gathering due to dead space (seroma, hematoma) wound separation, infection and injury in adjacent structures in the process of preparing the flap.

Miscalculations in patient coordination are a usual cause of postoperative complications. Such miscalculations in patients that receive reconstruction with a musculocutaneous flap include undermining any lingering medical conditions that are not related to the surgery, poor assessment of intravascular volume status and failing to observe the flap's viability and blood supply. Specifically, patients suffering SCI and pressure ulcers, that undergo debridement and reconstruction with musculocutaneous flaps will usually experience complications associated with spasticity due to the upper motor neuron syndrome. (35,36) When reconstruction is performed using a musculocutaneous flap, spasms can cause premature loosening of the sutures, flap stretching, prolonged recovery and possible failure of the reconstruction. More than 80% of patients with SCI present spasticity, causing significant further disabilities. Severe muscle spasms can be caused by various stimulating factors such as heat, cold and stretching of the urinary bladder (37,38). The symptoms are hard to control with medication. Often, muscle spasms can be intense in the postoperative period after treatment for pressure ulcers (39).

Finally, another complication is the recurring ulcer and osteomyelitis that often require surgical debridement and long-term treatment with antibiotics, resulting in prolonged hospitalization. These cases often re-

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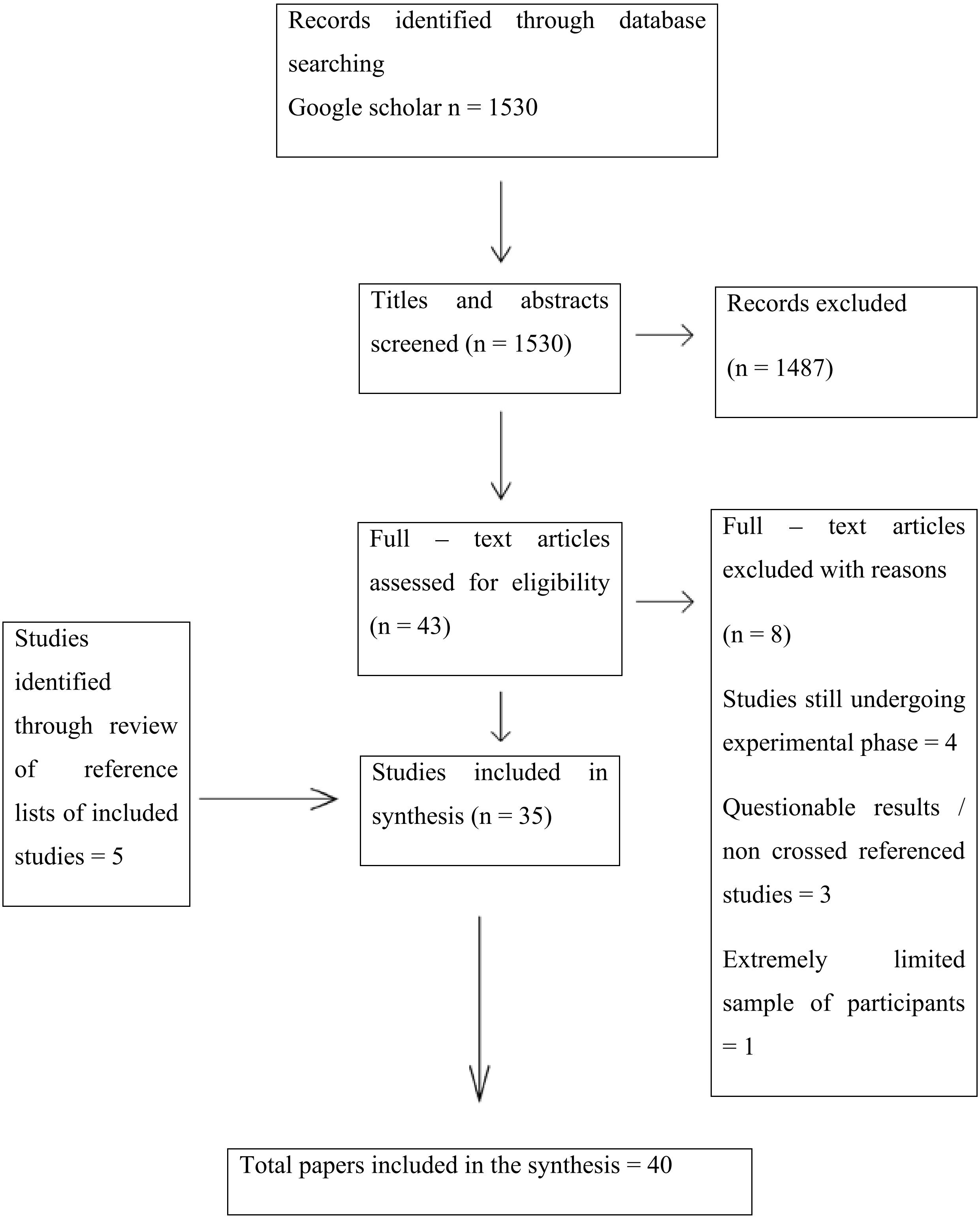
Table 1



quire a continuous dressing regime after the period of hospitalization. Following recovery, the unstable scar tissue makes the site susceptible to recurring ulcers, and avoiding pressure to the unstable scar tissue by respectively placing the patient often results in simultaneous pressure ulcers in other sites. Simultaneous trochanteric and ischial pressure ulcers, commonly referred to as the dual defect, present a reconstructive challenge (40).

Conclusion

The present study examined a serious problem experienced by patients with SCI. A large percentage of these patients will develop one or more pressure ulcers during their lives. Consequently, hospitalization time as well as morbidity rates are increased causing a great deal of uneasiness and psychological distress to the patients and their families. The issue of pressure sores in patients with SCI has generated global concern in the medical community, leading to the publishing of many studies regarding treatment. The treatment of pressure ulcers begins with prevention; thus, it is imperative to educate the patient's family in order to avoid the creation of an ulcer in the first place. Failure to prevent pressure ulcers results in the mandatory classification of the ulcer to identify the stage of the ulcer and determine how to treat it. In stages I and II the conservative approach is suggested while in stages III and IV the surgical approach with the use of flaps is preferred. Surgical treatment involves both surgery and appropriate management in the postoperative period. For this reason, the collective effort of several specialties such as orthopaedics, nutritionists, physiatrists, plastic surgeons as well as the contribution of the nursing staff and the physiotherapists is a huge undertaking in the medical community. Flaps revolutionized the treatment of advanced pressure ulcers, providing radical solution for the first time in history. Treatment with surgical flaps offers hope for recovery, improves the quality and prolongs the lives of these patients, and most importantly improves the psychology of all those involved in this situation, including families and caregivers.

Conflict of interest

The authors declared no conflicts of interest

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