Surgical Approaches for Cam Femoroacetabular Impingement: The Use of Multicriteria Decision Analysis

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Abstract

Background Currently, three surgical approaches are available for the treatment of cam femoroacetabular impingement (FAI), namely surgical hip dislocation (SHD), hip arthroscopy (HA), and the miniopen anterior approach of the hip (MO). Although previous systematic reviews have compared these different approaches, an overall assessment of their performance is not available.

Questions/purposes We therefore executed a multidimensional structured comparison considering the benefits, opportunities, costs, and risk (BOCR) of the different approaches using multicriteria decision analysis (MCDA).

Methods A MCDA using analytic hierarchical process (AHP) was conducted to compare SHD, HA, and MO in terms of BOCR on the basis of available evidence, institutional experience, costs, and our understanding of pathophysiology of FAI. A preclinical decision-making model was created for cam FAI to establish the surgical

approach that better accomplishes our objectives regarding the surgical treatment. A total score of an alternative's utility and sensitivity analysis was established using commercially available AHP software.

Results The AHP model based on BOCR showed that MO is the best surgical approach for cam FAI (normalized score: 0.38) followed by HA (normalized score: 0.36) and SHD (normalized score: 0.25). The sensitivity analysis showed that HA would turn into the best alternative if the variable risks account for more than 61.8% of the priority during decision-making. In any other decision-making scenario, MO remains as the best alternative.

Conclusions Using a recognized method for decision-making, this study provides supportive data for the use of MO approach as our preferred surgical approach for cam FAI. The latter is predominantly derived from the lower cost of this approach. Our data may be considered a proxy performance measurement for surgical approaches in cam FAI.

Level of Evidence Level II, economic and decision analyses. See the Guidelines for Authors for a complete description of levels of evidence.

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Introduction

Femoroacetabular impingement (FAI) is an alteration of hip morphology [25] associated with chondral [1, 5, 23, 32] and labral lesions [7, 10, 16] and is considered one of the most common causes of hip pain in young adults [18, 26]. More importantly, it incurs an implicit risk for development of end-stage osteoarthritis [16].

Although nonoperative management is the first line of treatment [17], persistent symptoms may lead to the need for surgical intervention. The goal of surgical intervention is to eliminate dynamic impacting between the femoral

head-neck junction and the labroacetabular complex [8, 14, 20] (especially during flexion and internal rotation of the hip) and to address the labral and chondral lesions.

Ganz et al. [16] have been credited with popularizing the concept of FAI and enhancing our understanding of this clinical entity. The same group described a safe and reproducible technique for surgical dislocation of the hip to address this condition [5, 15, 19]. In recent years, and with advances in arthroscopic techniques [7–9], surgical management of FAI using minimally invasive approaches has gained popularity. The intention of the surgical procedure, whether using hip arthroscopy (HA), surgical dislocation (SHD), or miniopen osteoplasty (MO) [24], is the same: to remove the source of impingement by performing osteoplasty of the femoral head-neck junction and/or the acetabular rim and address the labral and chondral lesion.

There are no prospective studies comparing arthroscopy and open surgery for treatment of FAI. The available information in the literature is only an analysis of reported outcomes of each procedure by different centers in systematic reviews [6, 10, 22]. Although HA generated lower rates of complication and faster rehabilitation than open techniques, the overall functional improvement has been comparable. The surgical skill set required to perform each of these approaches is sufficiently different so that no one surgeon may be adequately experienced to perform all three approaches proficiently. Hence, there are surgeons whose preference is to perform an open approach for treatment of FAI and others who believe FAI can be addressed by arthroscopy alone. To our knowledge, a multidimensional comparison among the three surgical approaches involving benefits, opportunities, costs, and risks (BOCR) is not available.

To address the lack of multidimensional appraisal in previous comparative studies, we designed the current study using multicriteria decision analysis (MCDA). Our goal was to compare these three surgical approaches considering BOCR on the basis of both the available evidence and our own surgical experience in FAI.

Patients and Methods

A preclinical model for cam FAI was created for this study based on our understanding of the FAI pathophysiology as follows: A young active patient is seen in the outpatient clinical setting with persistent hip pain after failed conservative treatment (6-week course of physical therapy and nonsteroidal antiinflammatory drugs) in the context of cam FAI without radiographic osteoarthritis. After a thorough evaluation, including a detailed history, physical examination, radiographs and MRI/arthrography, the clinician decides to suggest surgical treatment, which is

directed to repair bony alterations, labral tears, and chondral lesions. The clinician must evaluate: what the best approach is for surgical treatment in this patient considering BOCR of the different available alternatives.

Three surgical approaches (MO, HA, and SHD) were chosen to be included in the MCDA. MCDA methods were designed to help individuals make better choices when encountering decisions that involve different alternatives or dimensions. They are useful in linking hard data with specific subjective priorities, weighing tradeoffs between different outcomes, and incorporating the opinions of multiple decision-makers. Evidence-based, patient-centered clinical decision-making is composed of all of these features [12]. Analytic hierarchical process (AHP), the most frequently used method of MCDA for medical decision support [11], allows the decision-maker to design a hierarchical structure and weigh the tradeoffs between decision criteria and alternatives to facilitate improved clinical and management decisions [35] (Fig. 1).

The three surgical approaches were subjected to AHP analysis. According to Saaty, the developer of AHP, it is “a general theory of measurement that is used to derive ratio scales from both discrete and continuous paired comparisons. These comparisons may be taken from actual measurements or from fundamental scales, which reflect the relative strength of preferences and feelings. In its general form, AHP is a nonlinear framework for carrying out both deductive and inductive thinking without the use of syllogism by taking several factors into consideration simultaneously and allowing for dependence and for feedback, as it makes numerical tradeoffs in order to arrive at a synthesis or conclusion” [27, 30]. Dolan et al. summarized AHP in five steps [12]: (1) create a decision model by defining the decision goal, the options, and the criteria that will be used to determine how well the options meet the goal; (2) judge how well the options satisfy each criterion by making a series of pairwise comparisons among them using a nine-point scale ranging from “equally good” to “extremely better.” Another method is to incorporate the

Fig. 1 The basic structure of the analytic hierarchical process. It includes the goal, criteria, and alternatives levels.

direct weight of the priorities (the different priorities must sum 1.00). In the current study, both methods were used; (3) determine the relative priorities of the criteria in meeting the decision goal by making a series of pairwise comparisons among them using a nine-point scale ranging from “equally important” to “extremely more important” or to incorporate the direct weight of the priorities (the different priorities summing 1.00); (4) combine the option judgments and the criteria priorities to create a numeric ratio scale that indicates how well the options meet the goal; and (5) if desired, perform sensitivity analysis to explore the effects of changing the option judgments, criteria priorities, or both. To validate the comparisons, Saaty established the consistency ratio (CR) [29]. The CR provides information about logical consistency among pairwise comparison judgments. A perfectly consistent set of pairwise comparisons has a $CR = 0.0$ (no logical inconsistency). A $CR < 0.1$ is generally considered acceptable [12].

The analysis was conducted by the first author using SuperDecisionsTM software (Creative Decisions Foundation, Pittsburgh, PA, USA).

An AHP model was established as follows: The goal level is represented by the “best surgical approach for cam FAI.” The criteria level is composed by four criteria, namely “benefits,” “opportunities,” “costs,” and “risks.” For each one of the criterion, a subnet was created according to the software developers’ recommendation, some of them presenting subcriteria (Table 1). The alternatives level comprises the three surgical approaches (Fig. 2).

To establish the benefits provided by each one of the surgical approaches (subnet benefits), we used the average improvement in functional results observed for the different modalities. We decided to use the modified Harris hip score, because it is, thus far, the most frequently used method for functional assessment in patients with FAI [6]. The improvement described for HA was 26.4 points and 20.5 points for SHD in the systematic review conducted by Botser and colleagues [6]. The improvement that we observed and published for MO was 27 points [24]. These observations, converted in priority values, were 0.36 for HA, 0.37 for MO, and 0.28 for SHD. Because the cited articles did not differentiate the results according to the type of FAI, we used these values for our cam FAI model.

To establish the opportunities offered by each one of the surgical approaches (subnet opportunities), three technical factors were taken into consideration: (1) ability to successfully repair labral tears; (2) ability to successfully address chondral lesions; and (3) ability to correct the cam deformity (femoral head-neck junction bony bump). To establish consistency in pairwise comparisons among the

three surgical approaches with respect to this criterion, we used the clockwise system to compare access to the hip provided by each. HA and SHD provide the potential for circumferential access to the labroacetabular complex and acetabular cartilage. On the other hand, the surgical access provided by MO is reduced [21] and in our experience can reach from 9 o’clock to 3 o’clock (180°) when optimized. As input for the comparisons, we used the information provided by Tannast et al. [37], who described that 100% of the labral tears are located between 11 o’clock and 3 o’clock in cam FAI. Based on this information, the three surgical approaches were found to be potentially sufficient to address and treat 100% of the labral lesions in cam FAI. During the pairwise comparison, it provides equal priority (0.33 for each one, to sum 1.00) because all alternatives can accomplish the goal with equal proficiency. The second criterion is “successful treatment of chondral lesions.” According to Tannast and colleagues [37], all chondral lesions in patients with cam FAI are located between the 9 o’clock and 3 o’clock positions. Consequently, the three surgical approaches provide equal probability to address and treat chondral lesions. Therefore, the priorities are 0.33 for each one of the surgical approaches (to sum 1.00). The third criterion is “successful treatment of cam deformity,” meaning satisfactory correction of the femoral head-neck junction bony alteration. Regarding the potential to correct cam lesions, we used the information provided by Sussmann et al. [36]. The arc correction was chosen as a point of comparison between the approaches. They reported that HA can provide 125° of correction, whereas SHD can provide 130° . Because this value has not been established for MO, we used the same value of 130° as was established for SHD because of their similarity to an open surgical procedure (extrapolated data). According to these observations, the described arcs of correction were converted to priority values, which in turn were 0.34 for SHD and MO and 0.32 for HA (to sum 1.00).

To establish the costs (subnet costs), we used the monetary charges based on current procedural terminology (CPT) billing codes at our institution (Table 2). The US dollar values were then converted to priority values directly into priority values. The final priority values were 0.31 for HA, 0.22 for MO, and 0.46 for SHD.

To establish the risks (subnet risks), we used the concept of “avoidance of complications related to the surgical technique.” We used data from the study by Botser et al. [6] to obtain the rate of complications for HA and SHD. We excluded those complications that, from our perspective, are not inherent to the technique (ie, deep venous thrombosis) and those that were transient (ie, transitory pudendal nerve or transitory lateral cutaneous femoral nerve palsy). The final complication rates that were included in our models were 1.1% for HA and 8.7% for

Table 1. Input data, sources of information, and priority values used to construct the analytic hierarchy process framework for the cam FAI decision model

Input data		Alternatives									
Merits (priority)	Subnet criteria	Description	Reference used as source of information	Local priority within subnet	Global priority (priority in merits * local priority)	Surgical hip dislocation		Miniopen		Hip arthroscopy	
						Value	Priority	Value	Priority	Value	Priority
Opportunities (0.4)	Successful treatment of labral tears	What proportion of patients with acetabular labral lesions in the context of cam FAI can be adequately treated if I select alternative X as my surgical approach?	Tannast et al. [37]	0.33	0.13	100%	0.33	100%	0.33	100%	0.33
	Successful treatment of chondral lesions	What proportion of patients with acetabular chondral lesions in the context of cam FAI can be adequately treated if I select alternative X as my surgical approach?	Tannast et al. [37]	0.33	0.13	100%	0.33	100%	0.33	100%	0.33
	Successful treatment of cam deformity	The arc of correction at the femoral head-neck junction that can be achieved if alternative X is utilized	Sussmann et al. [36]	0.33	0.13	130°	0.34	130°*	0.34	125°	0.32
Risks (0.1)	Complications related to the surgical technique	What proportion of patients will suffer complications inherent to the surgical technique if I select alternative X as my surgical approach?	Botser et al. [6]	1	0.1	8.7%	0.78	1.3%	0.12	1.1%	0.10
Costs (0.1)	Costs	Costs of the surgical procedure if I select alternative X as my surgical approach	Cost in USD based on CPT codes (Table 2) was used for calculation	1	0.1	15,000.00	0.46	7250.00	0.22	10,200.00	0.31
Benefits (0.4)	Benefit	Average improvement expected in modified Harris hip score if I select alternative X as my preferred surgical approach	Data contained in Botser et al. [6] and Parvizi et al. [25]	1	0.1	20.50	0.28	27.00	0.37	26.40	0.36

* Data extrapolated; FAI = femoroacetabular impingement; CPT = current procedural terminology.

Fig. 2 The structure of the BOCR model used for the current study is depicted.

Table 2. Current Procedural Terminology (CPT) billing codes used for the costs calculation based on our institutional data

Pathology	Procedure	CPT codes billed	Cost (USD)
Cam FAI (with the assumption of labral and chondral lesions)	Hip arthroscopy	29914	3000
		29916	4000
		29862	3200
	Mini open	27120	4125
		27179	3125
	Surgical hip dislocation	27299	15,000

CPT code Description

29914	Arthroscopy, hip, surgical; with femoroplasty (ie, treatment of cam lesion)
29916	Arthroscopy, hip, surgical; with labral repair
29862	Arthroscopy, hip, surgical; with débridement/shaving of articular cartilage (chondroplasty), abrasion arthroplasty, and/or resection of labrum
27120	Acetabuloplasty (eg, Whitman, Colonna, Haygroves, or cup type)
27179	Open treatment of slipped femoral epiphysis; osteoplasty of femoral neck (Heyman-type procedure)
27299	Unlisted procedure, pelvis or hip

FAI = femoroacetabular impingement.

SHD. For MO, because we were interested on our own technique, we used our previously published data to establish a complication rate of 1.3% [24]. The final priority values were 0.10 for HA, 0.12 for MO, and 0.78 for SHD.

The final goal (“best surgical approach”) was calculated by combining the different subnet’s priority results, providing a BOCR summary score. The additive negative (subtractive) formula was chosen as recommended by the software creators [28] as well as by Wijnmalen [39]. The

formula considers costs and risks as negative additive factors (negative features) affecting benefits and opportunities (positive features). The BOCR score formula is summarized as follows:

$$\begin{aligned} & \text{weight (benefits)} * \text{priority (benefits)} \\ & + \text{weight (costs)} * (-\text{priority [costs]}) \\ & + \text{weight (opportunities)} * \text{priority (opportunities)} \\ & + \text{weight (risks)} * (-\text{priority [risks]}) \end{aligned}$$

A sensitivity analysis was performed to evaluate the robustness of the decision accomplished [13].

As a method to assess the uncertainty of our model, we evaluated the “rank-reversal” phenomenon, in which the ranking of alternatives is reversed after adding or excluding an alternative [29, 38].

Results

The main AHP model as well as the subnets had a CR < 0.1. The results obtained showed that MO is the best alternative to treat a patient with cam FAI in the context of labral and chondral lesions (normalized value: 0.38) followed by HA (normalized value: 0.36) and then SHD (normalized value: 0.26) (Fig. 3).

The sensitivity analysis showed that regardless of the importance allocated to the criteria “benefits,” “opportunities,” or “costs” during decision-making, the order in which the alternatives were ranked is not affected. On the other hand, the sensitivity analysis showed that if the priority allocated to “risks” is higher than 0.618, the

alternative HA comes to be the preferred one followed by MO and SHD.

No rank-reversal phenomenon was observed in this model.

Discussion

Using the available literature and our own surgical experience, we were able to assemble a MCDA model to compare the attributes of three different surgical approaches for treatment of cam FAI, namely HA, SHD, and MO. After the establishment of a system of priorities based on our understanding of the FAI pathophysiological process, we demonstrated that from our perspective, MO has a higher BOCR score than SHD and HA. The presented results support the use of MO as our preferred method to treat patients with cam FAI.

This study has some limitations that should be noted. First, the presented model was generated from our particular perspective, as permitted by the AHP, so we suspect that these results will not generalize to lower volume surgeons or surgeons inexperienced with one or more of the approaches. Second, the sources of uncertainty in AHP models are multiple and have been extensively discussed in the literature [31], including some modifications proposed to deal with this problem [4]. Zahedi and colleagues divided judgmental uncertainty into two forms: external and internal source of uncertainty [40, 41]. The former refers to the environment for collecting performance data of the criteria. The latter is caused by the decision-maker because of the limited or insufficient information. In our models,

Fig. 3 AHP analysis results are shown. Raw values: priority values for each alternative are retrieved directly from the matrix of the network with no additional calculations. Normal values: the raw priority values for each one of the alternatives are summed and then each element is divided by the sum. The elements in the normalized priority values sum to 1. Ideal values: each raw priority value is divided by the largest so that the best alternative gets a priority of 1 and the others get their proper proportion less than 1.

there are several external and internal sources of uncertainty, which mainly are a function of the variability of the studies included. It is well known that the quality of the literature reporting outcomes of these procedures, especially HA and SHD, portrays great discrepancy among the indications for surgical treatment, as shown by Ayeni and colleagues in two papers [2, 3], so the outcomes presented in the literature are difficult to assess and apply. Probably the same phenomenon is valid for miniopen surgery [6]; thus, we decided to use our institutional data previously published. Because level I evidence comparing the three surgical alternatives is not available, we believe that the inclusion of the systematic review by Botser and colleagues [6] provides our models with the best available evidence. In addition, the lack of information regarding some of the criteria in our models was resolved by extrapolating information from hard data similar in nature. In consequence, these data might not be completely accurate. As a method to assess the uncertainty of our models, we evaluated the “rank-reversal” phenomenon, in which the ranking of alternatives is reversed after adding or excluding an alternative [29, 38]. Rank-reversal is intimately related to uncertainty, so we considered it to address this shortcoming. The rank-reversal phenomenon was not observed in our model.

Also, the available information in the literature did not allow the MCDA model to evaluate the influence of learning curve on the eventual outcome of each. In addition, the available studies reporting the outcome of each procedure are by surgeons or centers that perform a relatively high volume of these procedures. Thus, it is not known how each of these approaches would perform in the hands of low-volume surgeons or centers. The problem is that the available literature does not make a distinction between high-volume versus low-volume surgeons nor does it provide comparative data on the outcome of two different procedures used by the same surgeon. Expert-based surgical delivery of care is an established method in medicine. However, we argue that this issue applies to any outcome reports that we see in orthopaedics.

Finally, the cost for these procedures was determined using a single institution's charges on the basis of CPT codes that may not be reflective of all centers. Despite this, the costs that we used to study HA are very similar to those used previously to calculate the cost-effectiveness of this particular procedure in the west coast of the United States [33]. For this reason, we believe that our conclusions are valid.

The miniopen surgery had a higher BOCR total score for the treatment of cam-type FAI. The latter relates to the low rate of complications that we observed [24] and, most importantly, the lower cost of this procedure. Despite the minimal difference observed between MO and HA, the sensitivity analysis based on the variables benefits, costs,

and opportunities showed that our results are robust. On the other hand, our results can be modified in favor of HA if the priority allocated to the variable risks increases. SHD had a lower BOCR total score than MO and HA, mainly as a result of the high rate of complications described as well as the higher costs. An interesting categorization of the type of complications presented after SHD was presented recently by Sink and colleagues [34]. Probably, the use of this classification system may be beneficial to be applied in all FAI literature to make the comparison among the different surgical strategies more consistent. It is plausible that the inclusion of this classification system in our models may generate changes in the total scores presented, especially for SHD. Beyond our results, there appears to be minimal difference in the calculated benefits among the three procedures in their ability to treat FAI. However, SHD appears to be associated with a higher cost. It is remarkable that, to date, there is no a particular CPT code to classify SHD; thus, the one that is used is nonspecific. This fact may explain the higher cost when compared with HA and MO.

In conclusion, this analysis, which used a recognized method for medical decision-making based on subjective prioritization, supports our choice of MO as our preferred method to treat cam FAI. Our data may be considered a proxy performance measurement for these procedures, mainly because of the inclusion of the variables BOCR during our analysis.

References

1. Anderson LA, Peters CL, Park BB, Stoddard GJ, Erickson JA, Crim JR. Acetabular cartilage delamination in femoroacetabular impingement. Risk factors and magnetic resonance imaging diagnosis. *J Bone Joint Surg Am*. 2009;91:305–313.
2. Ayeni OR, Naudie D, Crouch S, Adili A, Pindiprolu B, Chien T, Beaulé PE, Bhandari M. Surgical indications for treatment for femoroacetabular impingement with surgical hip dislocation. *Knee Surg Sports Traumatol Arthrosc*. 2012 Oct 13 [Epub ahead of print].
3. Ayeni OR, Wong I, Chien T, Musahl V, Kelly BT, Bhandari M. Surgical indications for arthroscopic management of femoroacetabular impingement. *Arthroscopy*. 2012;28:1170–1179.
4. Banuelas R, Antony J. Modified analytic hierarchy process to incorporate uncertainty and managerial aspects. *Int J Prod Res*. 2004;42:3851–3872.
5. Beck M, Leunig M, Parvizi J, Boutier V, Wyss D, Ganz R. Anterior femoroacetabular impingement: part II. Midterm results of surgical treatment. *Clin Orthop Relat Res*. 2004;418:67–73.
6. Botser IB, Smith TW Jr, Nasser R, Domb BG. Open surgical dislocation versus arthroscopy for femoroacetabular impingement: a comparison of clinical outcomes. *Arthroscopy*. 2011;27:270–278.
7. Byrd JW. Hip arthroscopy utilizing the supine position. *Arthroscopy*. 1994;10:275–280.
8. Byrd JWT, Jones KS. Arthroscopic femoroplasty in the management of cam-type femoroacetabular impingement. *Clin Orthop Relat Res*. 2009;467:739–746.

9. Byrd JWT, Jones KS. Hip arthroscopy in athletes: 10-year follow-up. *Am J Sports Med.* 2009;37:2140–2143.
10. Clohisy JC, St John LC, Schutz AL. Surgical treatment of femoroacetabular impingement: a systematic review of the literature. *Clin Orthop Relat Res.* 2010;468:555–564.
11. Dolan JG, Boohaker E, Allison J, Imperiale TF. Patients' preferences and priorities regarding colorectal cancer screening. *Med Decis Making.* 2013;33:59–70.
12. Dolan JG. Multi-criteria clinical decision support: a primer on the use of multiple criteria decision making methods to promote evidence-based, patient-centered healthcare. *Patient.* 2010;3:229–248.
13. Erkut E, Tarimcilar M. On sensitivity analysis in the analytic hierarchy process. *IMA J Management Math.* 1991;3:61–83.
14. Field RE, Rajakulendran K. The labro-acetabular complex. *J Bone Joint Surg Am.* 2011;93(Suppl 2):22–27.
15. Ganz R, Gill TJ, Gautier E, Ganz K, Krügel N, Berlemann U. Surgical dislocation of the adult hip: a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br.* 2001;83:1119–1124.
16. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;417:112–120.
17. Hunt D, Prather H, Harris Hayes M, Clohisy JC. Clinical outcomes analysis of conservative and surgical treatment of patients with clinical indications of prearthritic, intra-articular hip disorders. *PM R.* 2012;4:479–487.
18. Jaber FM, Parvizi J. Hip pain in young adults: femoroacetabular impingement. *J Arthroplasty.* 2007;22:37–42.
19. Lavigne M, Parvizi J, Beck M, Siebenrock KA, Ganz R, Leunig M. Anterior femoroacetabular impingement: part I. Techniques of joint preserving surgery. *Clin Orthop Relat Res.* 2004;418:61–66.
20. Leunig M, Huff TW, Ganz R. Femoroacetabular impingement: treatment of the acetabular side. *Instr Course Lect.* 2009;58:223–229.
21. Malik AK, Chou DTS, Witt JD. Anterior approaches to the hip for the treatment of femoro-acetabular impingement: a cadaveric study. *Hip Int.* 2010;20:482–488.
22. Matsuda DK, Carlisle JC, Arthurs SC, Wierks CH, Philippon MJ. Comparative systematic review of the open dislocation, mini-open, and arthroscopic surgeries for femoroacetabular impingement. *Arthroscopy.* 2011;27:252–269.
23. McCarthy JC, Lee J-A. History of hip arthroscopy: challenges and opportunities. *Clin Sports Med.* 2011;30:217–224.
24. Parvizi J, Huang R, Diaz-Ledezma C, Og B. Mini-open femoroacetabular osteoplasty: how do these patients do? *J Arthroplasty.* 2012;27:122–125.e1.
25. Parvizi J, Leunig M, Ganz R. Femoroacetabular impingement. *J Am Acad Orthop Surg.* 2007;15:561–570.
26. Plante M, Wallace R, Busconi BD. Clinical diagnosis of hip pain. *Clin Sports Med.* 2011;30:225–238.
27. Saaty RW. The analytic hierarchy process—what it is and how it is used. *Math Model.* 1987;9:161–176.
28. Saaty TL, Özdemir MS. *The Encyclicon: A Dictionary of Decisions With Dependence and Feedback Based on the Analytic Network Process.* Pittsburgh, PA, USA: R W S Publications; 2005.
29. Saaty TL, Vargas LG. Uncertainty and rank order in the analytic hierarchy process. *Eur J Oper Res.* 1987;32:107–117.
30. Saaty TL. How to make a decision: the analytic hierarchy process. *Eur J Oper Res.* 1990;48:9–26.
31. Sajjad Zahir M. Incorporating the uncertainty of decision judgements in the analytic hierarchy process. *Eur J Oper Res.* 1991;53:206–216.
32. Sampson TG. Arthroscopic treatment for chondral lesions of the hip. *Clin Sports Med.* 2011;30:331–348.
33. Shearer DW, Kramer J, Bozic KJ, Feeley BT. Is hip arthroscopy cost-effective for femoroacetabular impingement? *Clin Orthop Relat Res.* 2012;470:1079–1089.
34. Sink EL, Beaulé PE, Sucato D, Kim Y-J, Millis MB, Dayton M, Trousdale RT, Sierra RJ, Zaltz I, Schoenecker P, Monreal A, Clohisy J. Multicenter study of complications following surgical dislocation of the hip. *J Bone Joint Surg Am.* 2011;93:1132–1136.
35. Sloane EB, Liberatore MJ, Nydick RL. Medical decision support using the Analytic Hierarchy Process. *J Healthc Inf Manag.* 2002;16:38–43.
36. Sussmann PS, Ranawat AS, Lipman J, Lorch DG, Padgett DE, Kelly BT. Arthroscopic versus open osteoplasty of the head-neck junction: a cadaveric investigation. *Arthroscopy.* 2007;23:1257–1264.
37. Tannast M, Goricki D, Beck M, Murphy SB, Siebenrock KA. Hip damage occurs at the zone of femoroacetabular impingement. *Clin Orthop Relat Res.* 2008;466:273–280.
38. Wang Y-M, Elhag TMS. An approach to avoiding rank reversal in AHP. *Decis Support Syst.* 2006;42:1474–1480.
39. Wijnmalen DJD. Analysis of benefits, opportunities, costs, and risks (BOCR) with the AHP-ANP: a critical validation. *Math Comput Model.* 2007;46:892–905.
40. Zahedi F. The Analytic Hierarchy Process—a survey of the method and its applications. *Interfaces.* 1986;16:96–108.
41. Zahedi F. Group consensus function estimation when preferences are uncertain. *Oper Res.* 1986;34:883–894.