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Mid-term outcome after arthroscopic treatment of femoroacetabular impingement: development of a predictive score

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Abstract

Purpose: To build a post-arthroscopy outcome-predictive score (POPS) associated with the likelihood of lasting benefit after arthroscopic treatment of femoroacetabular impingement (FAI) and based solely on unambiguous preoperative information.

Methods: A population of 220 FAI patients, operated on with standard techniques by orthopaedic surgeons trained in hip arthroscopy in 6 different centres, was evaluated physically or by telephone interview 2 to 5 years after surgery. The criteria of successful mid-term outcome (SMO) were agreed upon by all authors. A multivariate logistic regression, adjusted for patient's age and centre, was applied to predict SMO. In the model, the variables associated with the outcome were included and the relative ORs (odds ratios) were used to compute the FAI-POPS (FAI - post-arthroscopy outcome-predictive score). A ROC (receiver operating characteristic) curve was plotted and the optimum cut-off was calculated.

Results: 155 patients out of 220 showed a successful mid-term outcome. The optimum cut-off of FAI-POPS was calculated to be 6.3 and with this threshold it proved a sensitivity of 0.66 and a specificity of 0.69, a positive predictive value of 0.84 and a negative predictive value of 0.46.

Conclusions: The standard arthroscopic treatment of FAI resulted in satisfactory persistent symptom relief for about 70% of patients. No or minimal osteoarthritis, short time elapsed from the appearance of symptoms and high preoperative modified Harris Hip Score are independent predictive factors of SMO. The FAI-POPS is obtained as sum of 3 odds ratios corresponding to the above prognostic factors and is a useful predictor of mid-term outcome after conventional arthroscopic FAI treatment.

Keywords

Femoroacetabular impingement, hip arthroscopy, multivariate analysis, outcome, score

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Introduction

The mid-term outcome (outcome assessed 2–5 years postoperatively) of arthroscopic treatment of femoroacetabular impingement (FAI) is poorly predictable, even when the treatment conforms to validated technical standards and the indications follow strict criteria.[1] The largest systematic reviews disagree about basic data such as the reoperation rate, which ranges in the mid-term between 4.03% and 11.3%.[1,2]

To date no scores, nor tests have been validated for the prediction of the mid-/long-term effects of arthroscopic osteochondroplasty,[3] neither are any patient-reported outcome measures (PROMs) accepted as gold standards for FAI patients' evaluation.[4]

The purpose of the present study is to build a post-arthroscopy outcome-predictive score (POPS) that is associated with the likelihood of a lasting benefit after arthroscopic treatment of femoroacetabular impingement (FAI) and is based solely on unambiguous preoperative information. Our hypothesis is that a number of objective and "easy-to-detect" preoperative variables may be used to compute a predictive score associated with the expected outcome 2–5 years after surgery, given that the patient is operated on by a trained hip arthroscopist who employs standard and validated techniques.

Methods

A population of FAI patients, operated on by 6 orthopaedic surgeons skilled in hip arthroscopy (being members of the Hip Faculty of SIA, Italian Society of Arthroscopy) in 6 different centres, was evaluated physically or by telephone interview 2 to 5 years after surgery. Informed consent was obtained from all patients who agreed to participate.

The study, observational and retrospective, was notified to the responsible Ethics Committees according to Italian laws and regulations.

Inclusion and exclusion criteria

Inclusion criteria: FAI cases treated with hip arthroscopy 2 to 5 years previously, whose preoperative variables listed below were fully available.

Exclusion criteria: procedures performed during the learning curve of each surgeon (first 30 hip arthroscopies for FAI), revision procedures, labrum reconstruction with graft, advanced techniques of cartilage regeneration (autologous matrix-induced chondrogenesis, autologous chondrocyte implantation, matrix-induced autologous chondrocyte implantation, etc.) except microfractures, coexistence of another primary joint disease (chondromatosis, pigmented villonodular synovitis, etc.), age $<$ 17 years.

According to these criteria, 220 cases out of 1117 were included, all of which were unilateral. No subject was lost to follow-up, since whoever was not available for a visit, was at least interviewed by telephone. The population under study, chiefly young-adult (mean age is 34 years, ranging from 17 to 64) with a 3:2 males-to-females ratio, was mostly affected by mixed type impingement with no or mild osteoarthritis and symptoms lasting for 17.9 months on average before surgery.

Preoperative data

Preoperative data, with particular attention to those which might be outcome-predictive according to the existing literature and to experts' opinion, were extracted from clinical records and imaging, anonymised and collected in a spreadsheet (Supplementary material; Spreadsheet 1):

- Age: some authors state that younger patients have more favourable outcomes,[5] although other experts disagree;[6]
- BMI (body mass index): recently, BMI was found to be a weak negative predictor of post-arthroscopy outcome;[7]
- Symptoms duration: a positive correlation with the worse outcome has been observed;[8]
- Preoperative mHHS (modified Harris Hip Score): higher preoperative scores have been associated with higher postoperative scores;[9]
- Job (sedentary; active – such as those requiring frequent movement; physically demanding – such as manual labour);
- Sport (none, occasional/recreational, amateur, semi-pro, pro): professional athletes seem to have (or declare) better results after hip arthroscopy, probably for motivational reasons;[10]
- Having 1st- and 2nd-degree relatives affected by hip osteoarthritis: genetic factors might contribute to hip joint degeneration;
- Type of impingement (cam/pincer/mixed): pincer FAI seems to have a worse prognosis;[11]
- α angle in anteroposterior (AP) and axial view: the size of the femoral deformity might be proportional to the joint damage;
- Lateral centre-edge (LCE) angle: acetabular dysplasia is a well-known negative predictor in FAI corrective surgery,[12] while coxa profunda might not influence the outcome if properly addressed;[13]
- Tönnis grade of osteoarthritis (0–3): preoperative osteoarthritis is a clear negative predictor.[14]

No magnetic resonance imaging (MRI)-related data were recorded and analysed since they depend on the machine's technical features and set-up and their interpretation, especially as far as cartilage is concerned, is not unambiguous.[15]

Outcome-related data

Postoperative outcome-related variables were assessed during follow-up visits or with telephone interviews (depending on patients' availability) and recorded on the same spreadsheet (Supplementary material; Spreadsheet 1):

- Satisfaction (dichotomous): "would you do it again (should you need it on the other side)?" (Yes/No);
- Satisfaction Numerical Rating Scale (NRS): 1-10 (1 = very unsatisfied, 10 = very satisfied);[16]
- Postoperative mHHS: it is proved to be related to patients' satisfaction after hip arthroscopy and to patients' Quality of Life.[17-20] Furthermore, the calculation through telephone interview is fairly reliable;[21]
- Return to sport: yes (how many months later, same level/lower level according to Tegner Activity level)/no/n.a. (not applicable, for premorbid sedentary patients);
- Reoperations: no/revision hip arthroscopy/total hip replacement (THR).

Definition of successful mid-term outcome

The successful mid-term outcome (SMO) was agreed upon as follows: "satisfaction (dichotomic) = yes AND satisfaction NRS ⩾ 7 AND postoperative mHHS ⩾ 90 AND return to sport = yes (or n/a) AND reoperations = no". Any other combination is classified as unsatisfactory. N/a (not applicable) is used for sedentary patients, for which the answer about return to sports may be considered irrelevant. Revision arthroscopy and THR are analysed together as "reoperations" since the number of events is too small to consider them separately.

Statistical analysis

Crude associations between outcome (SMO) and preoperative variables are assessed through chi-square or Fisher's test and Wilcoxon-Mann-Whitney test, according to their pattern of distribution. Multiple logistic regression was performed with SMO as outcome and preoperative data as explanatory variables, to develop a score able to predict a successful mid-term outcome (SMO+) or a mid-term failure (SMO-). The preoperative variables with a p-value < 0.10 in the univariate analysis were tested in the multivariate model adjusted for patient's age and centre, and their significance was reassessed. Statistically non-significant variables were then excluded, while the others were confirmed as SMO predictors.

The model permits to calculate the weights (odds ratio, [OR]) to be applied to each predictor to generate an additive score (FAI – post-arthroscopy outcome-predictive score, FAI-POPS) linked to the likelihood of SMO and computed as follows:

$$\text{FAI-POP Score} = OR_1 x_1 + OR_2 x_2 + \ldots + OR_n x_n$$

A ROC (receiver operating characteristic) curve was finally plotted in the plane (1-specificity) X sensitivity and the optimum cut-off was calculated according to the Youden's index.[22]

If the score is at least equal to this ideal threshold, a favourable mid-term outcome is predicted (SMO+); if the score is lower, an unfavourable outcome is predicted (SMO-). The comparison of the prediction with the real mid-term outcome, assessed according to the pentavariable definition of SMO, allows classification of patients as true positive, true negative, false positive, false negative. Hence sensitivity, specificity, accuracy and predictive values may be calculated as for any other test.

Results

After a mean elapsed time of 37.5 months (from 24 to 60), 155 patients out of 220 (70.45%) had a successful mid-term outcome (SMO+) and 65 failed one or more criteria of success (SMO-). 200 patients (90,91%) would repeat the procedure if needed, with a median satisfaction NRS as high as 9/10. 21 patients (9.5%) had further surgery (6 revision hip arthroscopies and 15 THRs). Distributions of preoperative variables are shown in Table 1.

The patients who had a successful mid-term outcome (SMO+) were younger than SMO- cases (median of age: 32 vs. 38, $p = 0.0009$), had a lower Tönnis grade (gr. 0 in 37.4% vs. 16.9%, $p < 0.0001$), a lower duration of symptoms (< 1 year 33.6% vs. 15.4%, $p = 0.0003$), a higher preoperative mHHS (>72 in 53.6% vs. 23.1%, $p = 0.0001$) and a lower α angle in AP view (median: 55° vs. 70°, $p < 0.0001$). Moreover SMO+ patients were more often operated in some centres (e.g. E, F) than in others (e.g. A), with large variability of outcomes likely related to slightly different patient selection criteria. In the multivariate logistic regression (Table 2), adjusted for patient's age and centre where the patient was operated, the probability to be SMO+ decreased with symptoms duration and Tönnis grade, whilst it increased with preoperative mHHS. Other preoperative variables lost significance (α angle in AP view, type of impingement, hip osteoarthritis in relatives). The 3 confirmed variables were considered as risk factors for the prediction of SMO

Table 1. Distribution of preoperative variables stratified by mid-term outcome of surgery.

Preoperative variable	SMO-	SMO+	*p*-value[a]
Centre, n (%):			<.0001
A	13 (20.00)	5 (3.23)	
B	13 (20.00)	19 (12.26)	
C	18 (8.18)	16 (7.27)	
D	11 (16.92)	19 (12.26)	
E	8 (12.31)	56 (36.13)	
F	2 (3.08)	40 (25.81)	
Symptoms duration, n (%):			0.0003
<12	10 (15.38)	52 (33.55)	
12-18	28 (43.08)	76 (49.03)	
>18	27 (41.54)	27 (17.42)	
Preop mHHS, n (%):			0.0001
<64	33 (50.77)	42 (27.10)	
64–72	17 (26.15)	30 (19.35)	
>72	15 (23.08)	83 (53.55)	
Job/lifestyle, *n* (%):			0.3232
Active	19 (29.23)	59 (38.06)	
Physically demanding	15 (23.08)	25 (16.13)	
Sedentary	31 (47.69)	71 (45.81)	
Sport, *n* (%):			0.2656
None	12 (19.05)	17 (10.97)	
Occasional/recreational	35 (55.56)	91 (58.71)	
Amateur and professional	16 (25.40)	47 (30.32)	
Hip osteoarthritis in relatives, *n* (%):			0.0086
No	51 (78.46)	93 (60.00)	
Yes	14 (21.54)	62 (40.00)	
Impingement type, *n* (%):			0.0167
Cam	24 (36.92)	60 (38.71)	
Mixed	38 (58.46)	82 (52.90)	
Pincer	3 (4.62)	13 (8.39)	
Tönnis grade, *n* (%):			<0.0001
0	11 (16.92)	58 (37.42)	
1	28 (43.08)	77 (49.68)	
2-3	26 (40.00)	20 (12.90)	
Age [years], *n* (median):	65 (38)	155 (32)	0.0009
BMI [kg/m²], *n* (median):	65 (23.5)	155 (24.1)	0.7885
α angle (AP) [°], *n* (median):	65 (70)	155 (55)	<0.0001
α angle (axial) [°], *n* (median):	65 (68)	155 (68)	0.2717
LCE angle [°], *n* (median):	65 (33)	155 (34)	0.5527

SMO+, successful mid-term outcome; SMO-, failed 1 or more criteria of success; BMI, body mass index.
[a]Differences between SMO were assessed by the chi-square or Fisher's test (for categorical variables) and Wilcoxon-Mann-Whitney test (for continuous variables).

and the corresponding OR were inserted in the equation of FAI-POPS.

$$\text{FAI-POPS} = OR_{duration} + OR_{preop\ mHHS} + OR_{Tönnis}$$

The OR are obtained from the multivariate model (Table 2), rounding off the numbers to the first decimal place:

- $OR_{duration}$ = 2.7 if symptoms have lasted less than 12 months, 1.1 if between 12 and 18 months, 1 if more than 18 months;
- $OR_{preop\ mHHS}$ =0.3 if preoperative mHHS is <64, 0.4 if between 64 and 72, 1 if > 72;
- $OR_{Tönnis}$ = 7.7 if grade of osteoarthritis is 0, 4.2 if grade is 1, 1 if grade is 2 or 3.

Table 2. Multivariate logistic regression model for SMO+, -2Log L, OR (odds ratio), CI (confidence interval), $n = 220$.

Preoperative variables [a]	Mode	Reference	-2 Log L[b]	*p*- value	OR	CI 95%	
Symptoms duration [mo]	1. <12	3. >18	185.2	<.0001	2.7	0.9	7.9
	2. 12-18				1.1	0.5	2.7
Preop. mHHS	1. <64	3. >72			0.3	0.1	0.7
	2. 64-72				0.4	0.1	0.9
Tönnis grade	0	2-3			7.7	2.4	25.5
	1				4.2	1.6	11.1

mHHS, modified Harris Hip Score.
[a]Adjusted for centre and patient's age; [b]-2Log L (likelihood ratio).

Plotting the ROC curve (Figure 1), the FAI-POPS subtends an AUC (area under the curve) of 0.73; in other words, it is a reasonably accurate classifier. The score may vary between 2.3 and 11.4, with an optimum threshold set at 6.3 with the Youden's method.[22]

The likelihood of SMO in our population is 0.704 (155 out of 220 cases) and with the above threshold the test results in 103 true positive, 45 true negative, 20 false positive and 52 false negative cases, that means sensitivity is 103/(103+52) = 0.66 and specificity is 45/(45+20) = 0.69. The accuracy meant as prognostic effectiveness [23] is (103+45)/220 = 0.67.[23] The positive predictive value is 103/(103+20) = 0.84, while the negative predictive value is 45/(45+52) = 0.46 (Supplementary material; Spreadsheet 1).

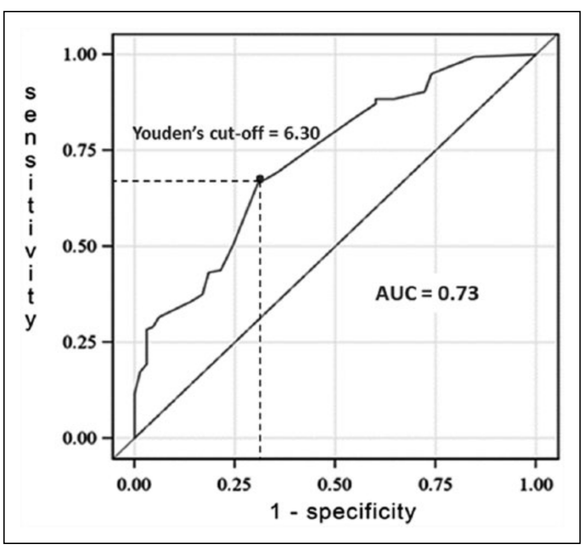

Figure 1. Receiver operating characteristic curve for FAI-POPS. The AUC represents the probability that the test ranks a randomly selected positive instance (SMO+) higher than a randomly selected negative one (SMO-). The Youden's cut-off is determined as the point of the ROC curve that is vertically farther from the no discrimination line (diagonal dotted line).

Discussion

The FAI-POPS is an additive score, which is able to differentiate the FAI patients who will benefit from hip arthroscopy in the next 2–5 years from those who will not. The test is fairly accurate if accuracy is measured by ROC AUC and when the cut-off is set at 6.3, the sensitivity is equal to 0.66 and the specificity to 0.69.[23]

Interestingly the multivariate logistic regression, adjusted for centre and age, confirmed only 3 predictors associated with the mid-term outcome: symptoms duration, Tönnis grade of osteoarthritis and preoperative mHHS. All the 3 variables are directly related to the grade of cartilage damage, that seems to be the only true obstacle against the beneficial effects of hip arthroscopy and FAI correction. However, several features commonly considered to be predictive turned out to be dependent upon other variables or poorly associated with the outcome (α angle, LCE angle, type of impingement, BMI, sport level, having relatives affected by hip osteoarthritis, etc.). This might depend on the longer time elapsed from surgery to results reassessment in the present study or on the particular definition of successful outcome that we set. For instance, Nabavi et al.[7] reported the outcome as "good" if mHHS had had a minimum 20 points increase 12 months after surgery and found the worker's compensation status might affect significantly the postoperative result, while belonging to the Armed Forces might improve it (possibly for motivational influences), although this effect was not statistically significant.

We chose not to consider these psychosocial factors as they did not occur in our population.

Intraoperative information (completeness of deformity correction, intraoperative grading of cartilage lesions, capsular and labral management, etc.)[24] was intentionally disregarded, since our aim was to generate an outcome-predictive score to be calculated before surgery (for instance in the outpatients' clinic), assuming that the pathology would have been treated with evidence-based techniques by a surgeon trained in hip arthroscopy.

Limitations

We acknowledge that this study has important limitations: preoperative data were always extracted from medical records while postoperative outcome-related data were often obtained by a visit, but seldom by telephone interview (whenever the patient could not be met in person). Only 220 subjects out of 1117 were included, which means 80.3% were excluded; this unusual selection was mostly due to the requisite that all the preoperative data should have been available in the medical records of included patients, which occurred rarely unless the patients were already enrolled in other clinical investigations. We agree that this choice might have determined a selection bias towards more motivated subjects.

We acknowledge also that classifying the outcome in 2 categories, success (SMO+, with all the 5 conditions verified) or failure (SMO-, with at least 1 condition not verified), means to reduce several intermediate outcomes to failure (e.g. satisfaction (dichotomic) = yes AND satisfaction NRS ⩾ 7 AND postoperative mHHS ⩾ 90 AND return to sport = no AND reoperations = no might be a satisfactory result for a recreational sportsman who was significantly symptomatic before arthroscopy, but our system would classify it as a treatment failure). This binary classification, conceived to focus the multivariate analysis on the very best results, might overestimate failures against successes, thus accounting for the difference between our series and other published ones, whose results seem to be more favorable. However, the crudest estimate of hip arthroscopy failure rate, the cumulative rate of revision arthroscopy and total hip replacement, shows that our series is well positioned close to those with the lowest reoperation rates, that range between 6.3% and 16.9% according to a recent review.[25] The present series displays an overall reoperation rate about 9.5%: revision arthroscopies account for 2.7% (6/220, none of which was converted to THR yet), and total hip arthroplasties for 6.8% (15/220).

Moreover, of the 3 preoperative variables included in the FAI-POPS equation, the Tönnis grade outweighs the other 2, so that in the extreme cases of no osteoarthritis (Tönnis 0) and frank osteoarthritis (Tönnis 2–3) the predicted outcome will be SMO+ and SMO- respectively, no matter which preoperative mHHS the patient had or how long the symptoms have been lasting before surgery. We admit that these ORs make the outcome prediction strongly influenced by a single risk factor for all these hips (Tönnis 0,2,3), but noticeably the largest group of hip arthroscopy patients have Tönnis 1 hips (mild degenerative changes) and in this group all 3 factors contribute similarly to the outcome prediction.

Lastly, experience and skills of each surgeon cannot be quantified objectively, however the inclusion in a dedicated teaching group by SIA, Italian Society of Arthroscopy suggests a satisfactory level of surgical proficiency.

Conclusions

The arthroscopic treatment of femoroacetabular impingement resulted in satisfactorily, persistent relief for about 70% of patients. No or minimal osteoarthritis, short time elapsed from the appearance of symptoms and a moderately high preoperative mHHS (>72) are independent factors predicting the likelihood of a successful mid-term outcome.

The FAI-postarthroscopy outcome-predictive score is obtained as sum of 3 odds ratios corresponding to the above prognostic factors and is a fairly accurate predictor of mid-term outcome after conventional arthroscopic FAI treatment. The score is not conceived to assess the eligibility of patients to treatment, as the limited sensitivity and low negative predictive value might lead to rule out several potential surgical candidates. However, subjects undergoing surgery who do not score 6.3 or more on FAI-POPS, should be advised of a reduced success rate in comparison with the majority of patients. The remarkable difference of OR between non-arthritic hips (Tönnis 0) and frankly arthritic hips (Tönnis 2–3) should discourage joint-preserving surgery in patent degenerative hip disease save in very young subjects or professional athletes.

FAI-POPS and any other predictive scores should not substitute the surgeon's judgement but may be used by surgeons to support the clinical decision-making, to evaluate their own results, to determine which FAI patients might be enrolled in clinical trials as good candidates for novel/alternative treatment strategies because their chances of long-lasting symptoms relief with standard arthroscopic techniques are low.

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Supplementary material

Supplementary material is available for this article online.

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