


Hypermobility, age 40 years or older and BMI $>30 \text{ kg m}^{-2}$ increase the risk of complications following peri-acetabular osteotomy

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Submitted 18 March 2020; Revised 17 July 2020; revised version accepted 15 August 2020

ABSTRACT

The peri-acetabular osteotomy (PAO) is a powerful surgical procedure for correcting symptomatic acetabular dysplasia, but it carries the potential for significant surgical complications. This study aims to determine the complication profile of PAO in a series performed by an experienced single surgeon. This was a retrospective review of 223 hips in 200 patients (23 bilateral, 22 males and 201 females). Complication data were collected from notes and radiographic review and graded according to a modified Dindo–Clavien classification. Each hip could be recorded as having more than one complication. Mean age at surgery was 28.8 years (range 13–48), mean weight was 70.9 kg (range 45–115 kg). Diagnosis was dysplasia in 185 hips, retroversion in 25 and a combination in 13. Mean follow-up was 26 months. In all, 61.4% of hips (137) had no complications; 74.0% had no complications or a Grade I complication (one that did not change management); 52 hips (23%) required pharmaceutical interventions (Grade II complications). Six hips (2.7%) suffered a major complication (Grade III or IV) as a direct consequence of the PAO. There were no Grade V complications (death). Hypermobility (Beighton's score of ≥ 6 , Odds ratio (OR) 2.525 $P=0.041$), age 40 years or older (OR 3.126 $P=0.012$) and BMI >30 (OR 2.506 $P=0.031$), but not Tonnis grade ($P=0.193$) increased the risk of more severe complications following a PAO. This single surgeon series from a high volume centre demonstrates that age 40 years or older and BMI $>30 \text{ kg m}^{-2}$ and hypermobility increase the risk of more severe complications.

INTRODUCTION

Acetabular dysplasia is associated with the pre-mature development of osteoarthritis [1]. Peri-acetabular osteotomy (PAO) is performed for symptomatic acetabular dysplasia [2, 3]. Good results have been reported with good outcomes reported in over three quarters of patients [3], with hips operated on with little or no osteoarthritic change surviving up to 20 years in 80% of cases [4]. However it is a technically challenging procedure, associated with a learning curve [2, 5]. Complications, especially in early cases in series have been reported [2, 6]. Even with experience there can be major complications in 6% of patients [7]. This figure is from a multicentre, multi-surgeon study

which used a standardized complication reporting method [8]. The rate of major complication was reported at one-year follow-up, and so potentially misses complications that occur beyond this period post-operatively. The aims of this study were to describe the complications and their rate at a longer follow-up interval following a minimally invasive PAO in a single centre by a single surgeon experienced in the procedure.

METHODS

Patient selection

This was a retrospective review and no ethical approval was required. The study was registered with the host

institution's clinical governance board. The 241 hips in 221 patients underwent PAO between May 2012 and December 2015. Clinical notes and radiographs were reviewed. Inclusion criteria were minimum 6-month follow-up, and complete radiographic and clinical documentation. Routine follow-up involves a review at 6 weeks, 12 weeks, 6 months and 1 year with continuing annual reviews. Exclusion criteria included previous pelvic surgery, concurrent surgical hip dislocation and undergoing PAO as the first stage of a revision procedure (seven hips). Eleven hips that were lost to follow-up, had incomplete radiographs or clinical documentation and were excluded. The remaining 223 hips in 203 patients who were included in the analysis.

Surgical procedure and follow-up

All the procedures were performed by the senior author at the host institution. Prior to this cohort the senior author had performed >300 osteotomies. The approach, surgical technique and outcomes have been described previously [9], but briefly summarized here: The patient is placed supine on radiolucent table. A transverse incision, of ~8–10 cm is made distal to the Iliac crest. The soft tissue is dissected off the anterior superior iliac spine (ASIS) to include the origin of the inguinal ligament and sartorius. The abdominal muscles are released off the iliac crest extending ~4–5 cm posterior to the ASIS. Distally the fascia over tensor fascia lata is incised for a distance of 5–6 cm and the muscle fibres are dissected off the fascia. The direct head of rectus femoris is then identified and the interval between iliopsoas and rectus femoris is developed, leaving rectus femoris attached to the anterior inferior iliac spine (AIIS). The fibres of iliocapsularis are elevated from the hip joint capsule, and a plane anterior to the hip capsule is developed to allow the passage of a specialized osteotome to the ischium where the first osteotomy is made. The division of superior pubic ramus is made under direct vision, after retracting the iliopsoas medially and clearing the soft-tissue attachments superiorly and inferiorly. The posterior column osteotomy is made under fluoroscopic control to meet the ischial cut. The osteotomy is completed after making the transverse iliac osteotomy with a saw. The acetabular fragment is then completely mobilized and the correction made and held with K-wires. Fixation of the acetabular fragment is usually by three fully threaded cortical screws. Standard thromboprophylaxis includes anti-embolism stockings, pneumatic calf compression pumps during surgery and low-molecular-weight heparin during the inpatient stay. Aspirin 150 mg for 3 weeks once daily is administered on discharge [10–12].

Patients are seen in the team's outpatient clinic at 6 weeks, 12 weeks, 6 months and 1 year post-operatively, and yearly thereafter. Supine anteroposterior pelvic radiographs of the pelvis are taken at each clinic visit until union of the osteotomies. Patients are mobilized 20 kg weight-bearing on the operated limb with crutches for 6 weeks. If radiographs are satisfactory at this follow-up weight-bearing is progressed to 30 kg for 3 further weeks, and then full weightbearing as tolerated with crutches thereafter. Unaided FWB is permitted by 12 weeks. Impact exercise is permitted at 5–6 months post-operatively.

Complication recording

Complications were recorded at clinical review as outlined above. Clinic notes and radiographs were retrospectively reviewed and recorded in a Microsoft Excel spreadsheet, and statistical analysis was performed using SPSS. Complications were graded according to a modified Dindo–Clavien grading system for hip preservation surgery [8]. Each hip could be recorded to have more than one complication. The most severe complication for each hip was also recorded and graded according to the classification system. Re-operations were considered as complications only if they were required to address a surgical complication of the PAO. Planned concomitant procedures (e.g. hip arthroscopy performed at a 12-week interval to address intra-articular pathology identified prior to the PAO) were not considered a surgical complication. Mean follow-up was 26 months (range 6–60 months).

A Grade I complication requires no treatment or deviation from routine post-operative care. Permitted therapeutic interventions include antiemetics, antibiotics, analgesia and physiotherapy. Examples include asymptomatic stress fractures that did not alter rehabilitation or weightbearing, Grade A heterotopic ossification [13] or minor wound problems. A Grade II complication is defined as one altering routine post-operative care, such as unplanned outpatient visits or pharmacological intervention not included in Grade I complications. Stress fractures that required altered rehabilitation were included here. Intra-articular injections or psoas tendon sheath injections were also considered Grade II complications. Grade III complications required surgical or inpatient management. These included emergency admissions for intravenous antibiotics, or washouts for wound infections, or procedures for delayed or non-union of any of the osteotomies. It is the senior author's practice to address intra-articular pathology arthroscopically at an interval after the PAO. These were considered concomitant interventions. Nine patients underwent arthroscopic procedures for FAI after their PAO. In two of these patients the arthroscopy was planned

Table I. Patient demographics

	Total	Male	Female
Number patients	200	21	179
Number of hips	223	22	201
Bilateral	23	1	22
Mean age (SD)	28.8 (7.7)	27.7 (7.8)	29.0 (6.1)

prior to or at the time of the PAO and occurred within 12 weeks of the index procedure, and so these two cases were not considered a Grade III complication. A Grade IV complication is life or limb threatening. The modified Dindo–Clavien classification considers conversion to a total hip replacement (THR) as a Grade IV complication, as is pulmonary embolism, permanent nerve injury or unplanned intensive care admission. A Grade V complication is death.

Statistics

Descriptive statistics are presented. To investigate the effect of obesity ($\text{BMI} > 30 \text{ kg m}^{-2}$), age 40 years or older, Tonnis grade and hypermobility (Beighton's score ≥ 6) on number of complications and severity of complications a cumulative odds multivariate ordinal logistic regression with proportional odds was run. Data were analysed using SPSS v20.0 (IBM, USA).

Patients. In 200 patients who underwent PAO between May 2012 and December 2015, 223 hips met the inclusion criteria. Twenty-two hips in 21 male patients underwent PAO (see Table I). The underlying pathology was acetabular dysplasia in 83% of patients. The 11.2% underwent PAO for retroversion and 5.8% had combined pathology. The 51.1% of patients had Tonnis Grade 0 and 44.8% had Tonnis Grade 1 osteoarthritis (Table II). The number of obese ($\text{BMI} > 30$) and hypermobile patients, comorbidities and prior surgical procedures are summarized in Table III.

RESULTS

In patients with dysplasia as the primary indication for PAO, the mean lateral centre edge angle (LCEA) was 18.8° (SD 7.5°) pre-operatively and post-operatively this was corrected to 31.7° (SD 6.9°). Sourcil angle was corrected from a mean 13.8° (SD 7.3°) to 3.6° (SD 3.9°). 137 hips (61.4%) had no complications (Table IV). 137 hips experienced no complication. 86 hips experienced a total of 120 complications (Table V). Of these, 28 (12.6%) hips had a Grade I complication (one that causes no deviation from routine post-operative care). Thus, 72.7% of hips underwent PAO without significant complication. There

Table II. Underlying diagnosis and level of degenerative change pre-operatively

Diagnosis	All hips	%	Male	%	Female	%
Dysplasia	185	83.0	17	78.3	168	83.6
Retro	25	11.2	3	13.0	22	10.9
Combined	13	5.8	2	8.7	11	5.5
Tonnis grade						
0	114	51.1	6	27.2	109	54.2
1	100	44.8	15	68.1	84	41.8
2	9	4.0	1	4.5	8	4.0

Table III. Associated conditions, comorbidities and prior surgical interventions in the patient group

Associated conditions	Total	%	Male	%	Female	%
Hypermobility	19	8.5	0.0	19	9.5	
BMI > 30	23	10.3	2	8.7	21	10.4
Comorbidities						
Asthma	6	2.7	1	4.3	5	2.5
DMI	1	0.4			1	0.5
JIA	1	0.4			1	0.5
Epilepsy	2	0.9	1	4.3	1	0.5
Osteoporosis	1	0.4			1	0.5
Cardiac	1	0.4			1	0.5
Previous surgery						
Previous surgical hip dislocation	4	1.8			4	2.0
Previous pelvis osteotomy	2	0.9			2	1.0
Previous hip arthroscopy	3	1.3	1	4.3	2	1.0
Von Willebrands	1	0.4			1	0.5
Perthes	2	0.9	2	8.7		

were 59 Grade II complications in 52 hips (23.3%). Forty-four of these were psoas tendon sheath injections following the PAO (Table VI). There were seven Grade III or IV complications in six hips (2.7%). Specifically, one patient went on to have a psoas tendon release having had two psoas tendon injections which provided temporary

Table IV. Most severe complication by modified Dindo–Clavien grade in number of hips (percentage in parenthesis)

Highest Dindo–Clavien grade	Number of hips with hypermobility		Number of hips with BMI ≥ 30		Number of hips with age 40 years or older		Total number of hips	
0	8	(3.1)	10	(4.5)	10	(4.5)	137	(61.4)
I	3	(1.3)	4	(1.5)	2	(0.9)	28	(12.6)
II	7	(2.2)	7	(3.1)	7	(3.1)	52	(23.3)
III	1	(0.9)	1	(0.4)	1	(0.4)	4	(1.8)
IV	0	(0.9)	1	(0.4)	2	(0.9)	2	(0.9)
V	0	(0)	0	(0)	0	(0)	0	(0)
Total	19	(9)	23	(10.3)	22	(9.9)	223	(100)

Table V. Number of complications sustained by most severe complication as graded by the modified Dindo–Clavien grade (percentages in parenthesis)

Dindo–Clavien grade	Number of complications			
	0	1	2	3
0	137 (60.1)	0 (0)	0 (0)	0 (0)
1	0 (0)	18 (8.1)	10 (4.5)	0 (0.4)
2	0 (0)	37 (16.6)	15 (6.7)	0 (0)
3	0 (0)	0 (0)	2 (0.9)	2 (0.9)
4	0 (0)	0 (0)	1 (0.4)	1 (0.4)
5	0 (0)	0 (0)	0 (0)	0 (0)
Total	137 (61.4)	55 (24.7)	28 (12.6)	3 (1.3)

symptomatic relief. Two patients developed wound infections that required washout, and one patient required a revision fixation. Two stress fractures were symptomatic enough to require surgery. One had synthetic bone grafting and united, and the other was plated and an arthroplasty performed at 15 months following the index PAO. This is classed as a Grade IV complication of which there was one other; a pulmonary embolism.

There were 25 stress fractures (11.2%). Three involved the posterior column, and 22 involved the inferior pubic ramus. Twelve of 25 stress fractures were associated with delayed union of the pubic osteotomy. Twenty of the stress fractures were asymptomatic and did not change management (Table VI). Three stress fractures warranted

a change in physiotherapy regime (delay to full weight bearing), and two required surgery (discussed above).

Ordinal logistic regression was used to assess whether, age 40 years or older, BMI $>30 \text{ kg m}^{-2}$, hypermobility, or Tonnis grade, influenced severity of the most severe complication as classified by the Dindo–Clavien grading system. The assumption of multicollinearity was met. The assumption of proportional odds was met for all independent variables as assessed by visual inspection of separate binomial logistic regression of the independent variables upon cumulative dichotomized dependent variables. The deviance goodness-of-fit test $\chi^2(51) = 44.595$ $P = 0.724$ indicating that the model was a good fit to the observed data, however many cells were sparse with zero frequencies in 54.7% of cells. However, the final model statistically significantly predicted the severity of the most severe complications over and above the intercept-only model, $\chi^2(6) = 15.394$, $P = 0.009$. Tonnis grade did not have a statistically significant effect on the severity of the most severe complication. The odds ratio that being aged 40 or over increased severity of complications was 3.126 (95%CI 1.291–7.569), Wald $\chi^2(1) = 6.384$ $P = 0.012$. The odds ratio that being hypermobile increased severity of complications was 2.559 (95%CI 1.039–6.308), Wald $\chi^2(1) = 4.168$ $P = 0.041$. The odds ratio that being obese with a BMI $>30 \text{ kg m}^{-2}$ increased severity of complications was 2.508 (95%CI 1.089–5.776), Wald $\chi^2(1) = 4.670$ $P = 0.031$.

DISCUSSION

Complications following PAO have been described [3, 6, 7, 14–17]. Major complications reported include major nerve injury (up to 10% [18, 19]), avascular necrosis of the femoral head [2], major blood loss (two cases in 71

Table VI. Number of complications and Dindo–Clavien grade

<i>Dindo–Clavien grade</i>							
1		2		3		4	
<i>Complication</i>	<i>No. of patients</i>	<i>Complication</i>	<i>No. of patients</i>	<i>Complication</i>	<i>No. of patients</i>	<i>Complication</i>	<i>No. of patients</i>
Stress fracture— asymptomatic	20	Stress fracture—change in rehab or follow-up	3	Stress fracture undergoing further surgery	2	Conversion to THR	1
Wound infection— oral antibiotics	9	Further injection— psoas	44	Wound infection requiring washout and IV antibiotics	2	PE	1
HTO	1	Further intra-articular injection	8	Revision fixation	1		
Delayed pubic union— asymptomatic	14	LFCN requiring medication	3	DVT	1		
Blood transfusion	1	Ischial pain requiring injection	1	Psoas release	1		
Medical or anaesthetic complication	1			Further arthroscopic intervention	0		
PT for psoas	5						
	52		59		7		2

Each hip could be graded to have more than one complication. HTO, heterotopic ossification; PT, physiotherapy; LFCN, lateral femoral cutaneous nerve; DVT, deep vein thrombosis; THR, total hip replacement; PE, pulmonary embolism.

[3]) and intra-articular fracture or osteotomy in up to 15% [2]. These high rates of complications are from cases performed before the turn of the century, and concentrate on serious complications during the learning curve [6, 15–17, 20].

More contemporary, prospectively collected data, from the ANCHOR group describes complications following PAO performed by 10 experienced surgeons [7]. There was an early follow-up visit at mean of 10 weeks, and a late visit at a mean of 14 months. In all, 177 hips presented for the latter visit and overall, nine Grade III and three Grade IV complications are reported, with a quoted 5.9% major complication rate (12 patients out of the original 205). No significant association between age, sex, BMI or comorbidities with complications could be identified. This study reports 223 hips from a single surgeon that had mean follow-up of 26 months. Cases with <6 months' were excluded from the analysis and final calculation of complication rates. None of the patients with short follow-up (<1 year) reported any major complications.

Two of the patients undergoing hip arthroscopies following PAO in this series were not classified as Grade III

complications. Although some authors advocate opening the joint at the time of the PAO [21], however, Thanacaroenpanich *et al.* [22] describe a higher complication rate for those having intra-articular pathology addressed at the time of the PAO, but also describe better visualization of intra-articular pathology arthroscopically compared with arthrotomy. It is also our opinion, based on the senior author's early experience, that intra-articular pathology can be better addressed with distraction arthroscopically. The arthroscopy is performed within 12 weeks of the PAO so that the patient's rehabilitation from the PAO is not delayed significantly. It may be argued that even those performed beyond this period are a continuation of the treatment of these patients and as such should not be classed as complications.

Excepting these two planned arthroscopies, we have reported all re-operations within the follow-up period as complications. It may be considered that these re-operations are on-going treatment for a symptomatic hip joint rather than a direct complication of the PAO [23]. The only THR in this study performed as a result of a complication of the PAO was performed alongside a

posterior column plating for a symptomatic ununited stress fracture.

There were no major nerve injuries, and deep infection rate in this series is comparable to the ANCHOR group's data. We do report a much higher rate of intra-articular injection and psoas tendon injection than the ANCHOR group. Forty-four patients had psoas tendon sheath injections and these are initiated if it is felt that psoas symptoms are delaying rehabilitation. It is suggested that movement of the acetabular fragment and therefore the psoas groove may result in psoas irritation. Only one patient subsequently underwent tendon release.

Our series has a much lower incidence of heterotopic ossification (HTO). One patient had minor HTO. Previous series have reported rates ranging from 5.6% (4/71) [14] to 21.2% (13/60) [18]. More recently 7.3% (13/177) [7] is reported, although only one patient underwent excision of HTO for symptoms. The lower rate of HTO in this series is most likely related to the approach where rectus femoris is not released and there is minimal dissection around the hip joint capsule which was not opened.

Ischial stress fractures are a common and under-reported complication [24]. We report 25 ischial stress fractures (11.2%), which is slightly less than the previously reported rate of 18.4%. Twelve patients with stress fractures had delayed union of the pubic osteotomy. This proportion is similar to that previously reported (62.5%). Synthetic bone graft is now used to bridge the osteotomy gap at the pubis in larger corrections, which may explain the slightly lower rate, of stress fractures although identifying these factors was not the intention of this work.

We show a 2.5 time increase in the risk of a more severe complication with a BMI of $>30 \text{ kg m}^{-2}$ which is consistent with previous data on obesity [25], however the threefold increase in the risk of a more severe complication with age 40 years or older seems to contradict the improved outcome with increasing age [26]. We show a 2.5 time increase risk of a more severe complication following a PAO in those patients who are hypermobile. This is the first work to identify this.

The lack of formal patient reported outcome data is a limitation of this work, but early outcomes have already been reported with this technique [9] and this study is intended to assess complications rather than outcomes. It can be argued that as a single surgeon series the generalizability of this work is also limited. However, this is a very large number from a single centre. We accept the limitations of retrospective review but the results are reported as a worst-case scenario. Furthermore, the length of follow-up, and low loss to follow-up minimizes selection and reporting bias.

Conclusion

PAO can be performed safely in a high-volume centre, with a 2.7% rate of major complication. Increased severity of complications are seen with age 40 years or older, obesity and hypermobility.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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