ORIGINAL STUDY — HIP

acta orthopaedica belgica, 2024, 90, 17-25

doi.org/10.52628/90.1.10974

Anterior approaches in acetabular fractures: a true learning curve analysis

M. CAUDRON, V. GERSET, C. TRONC, J. TONETTI, M. BOUDISSA

Centre Hospitalier Universitaire de Grenoble, CHU Grenoble, Service d'Orthopédie-Traumatologie, Grenoble, France.

Correspondence at: M. Caudron, Av. Reine Fabiola 9, 1340 Ottignies-Louvain-la-Neuve, Belgique, Email: martin.caudron@cspo.be

Today, acetabular surgeons in training have to learn ilioinguinal and anterior intrapelvic approaches (AIP). The aim of this study was to describe the 5-years learning curve of a surgeon. Objective was to assess clinical and radiological results; and to assess factors which could influence this learning curve. Between November 2015 and May 2020, patients with an acetabular fracture operated by the surgeon during the 5-years learning curve with an anterior approach were included in this single-center retrospective study based on a prospective database. Epidemiological, operative, clinical, radiological and complications data's were collected. To assess learning-curve effect the series was divided into two groups: first 2.5-years and last 2-years. Subgroup analysis were performed according to the surgical approach, to the reduction quality and the prognostic factors. In total, 46 patients were included, 23 in period 1 and 23 in period 2. 16 patients (35%) had ilioinguinal approach and 30 patients (65%) had modified Stoppa-Cole approach. At mean follow-up of 24 months, 38 patients (83%) were reviewed. Anatomical reduction (< 1 mm) was achieved in 28 patients (60.9%) with a 9% rate of perioperative complications and 37% rate of post-operative complications. In conclusion, this study gives a realistic overview of the learning curve of anterior approaches in acetabular fractures surgery. Our results should encourage surgeons, while keeping in mind how much this surgery can be challenging, with high rate of complications and difficulty to obtain a systematic anatomical reduction.

Keywords: acetabular fracture, learning curve, ilioinguinal, modified Stoppa-Cole, reduction quality, complications.
Level of evidence, III: retrospective study.

INTRODUCTION

Acetabular fractures are serious injuries whom surgical treatment is technically challenging with a reduction accuracy directly related to patient outcomes[1]. Recent epidemiological works have shown that the incidence of acetabular fractures in France increases in young patients and increases significantly in people over 60 years of age[2]. Accuracy of reduction and clinical outcomes depend on surgeons experience and some prognostic factors have been identified[3]. The description and the spread of anterior intrapelvic approaches (AIP) (modified Stoppa-Cole) have modified the surgical habits of acetabular surgeons. Rives et al and Stoppa et al have described this intra-abdominal surgical approach for the repair of groin hernias, then used by Cole and Bolhofner for open reduction and internal fixation (ORIF) of acetabular fractures[4-6]. Several series have reported the good results obtained with AIP approaches, most of them performed by experienced surgeons used to perform ilioinguinal approach[7-9]. Today, acetabular surgeons in training have to learn ilioinguinal and AIP approaches to get a complete overview of the surgical management of their patients. A recent survey have shown that the modified Stoppa-Cole approach has become the preferred anterior approach in North America, being especially favored by those more recently in practice[10].

Learning curve in acetabular fractures required many interventions and only few studies report the results of a learning curve[11,12]. According to Matta et al a learning curve with at least 50 acetabular fracture surgeries (both anterior and posterior approaches) is necessary to get 60% of anatomical reduction[13].

The aim of this study was to describe the 5-years learning curve of anterior approaches (ilioinguinal and AIP) of a trauma surgeon who intend to specialize in acetabular surgery in a French Trauma Center. The primary objective was to assess clinical and radiological results of this learning curve. The secondary objective was to assess factors which could influence this learning curve.

MATERIALS AND METHODS

Between November 2015 and May 2020, all patients with an acetabular fracture were operated by a single individual surgeon with an anterior approach were included. All patients were operated during the 5-years learning curve of the first author without assistance of any senior surgeons. When a second posterior approach was performed, only data from the anterior approach were collected.

Informed consent was obtained from all individual participants included in the study before discharge and our local ethics committee approved this retrospective study without changes in the standard cares.

Single-center retrospective study based on a prospective database. Epidemiological data, operative data, clinical results, radiological results and complications were collected. Patients were reviewed at 3 months, 6 months, one year and two years after treatment. A retrospective review for last follow-up data was performed.

The following epidemiological data were analyzed: sex ratio, age, mechanism of injury, Body-Mass Index (BMI), ASA score, Injury Severity Score (ISS), associated lesions, pre-operative anticoagulation, venous thrombosis and lung embolism were recorded[14,15]. The fracture patterns were classified on standard X-rays and preoperative CT scan according to Letournel classification by an independent observer[16]. Radiological prognostic factors such as roof impaction ("gull-sign"), femoral head protrusion, femoral head fracture and/or dislocation, floating hip were assessed[17-20].

Regarding operative data, delay between accident and surgery, operative time and blood loss were recorded. The per operative complications were also recorded.

Regarding clinical results, Merle d'Aubigne Postel (PMA) and Harris Hip Score (HHS) from the prospective database were collected at last follow-up[21,22]. Work status and sport activity before accident and at last follow-up were recorded and compared.

Reduction quality was assessed on a postoperative CT scan by an independent observer using Matta's criteria (anatomical, imperfect and bad reduction for a gap or a step ≤ 1 mm, 2-3 mm and > 3mm, respectively)[13]. Residual step and gap deformity were measured according to Borelli et al on each CT image[23].

Post-operative complications and reinterventions were recorded. Total hip replacement rate and its delay after acetabular surgery were collected.

To assess learning-curve effect the series was divided into two groups: first 2.5-years operated patients and last 2-years operated patients. Then subgroup analysis were performed according to the surgical approach (ilioinguinal versus modified Stoppa-Cole), the reduction quality according to Matta and the bad prognostic factors[13].

Statistical analysis was done using Statview 5.5 software (SAS Institute, Cary, NC, USA). Kruskall Wallis test and student test were applied to compare quantitative variables and the Chi-2 test and Mac Nemar test were applied to compare qualitative variables. Fisher exact test was applied for not parametric data. Values of p lower than 0.05 were taken to indicate significant differences.

RESULTS

During the study period, 46 patients were included, 7 women and 39 men with a mean age of 52 ± 18 years (20-89). Mechanism of injury was high energy trauma in 38 patients (83%) and low energy trauma in 8 patients (17%). The mean ISS score was 11 ± 5 (3-34)[15]. Epidemiological data and associated injuries are summarized in Table 1. Regarding pre-operative management 43 patients (93%) had trans-osseous traction, one patient presented an open fracture (2%) and one patient had an embolization (2%). Due to pre-operative phlebitis (4 patients, 8.7%) and pulmonary embolism (1 patient, 2%), 5 patients had pre-operative curative anticoagulation (10.9%). Three patients (6.5%) had pre-operative sciatic nerve injuries.

Thirty-one patients (67.4%) were worker before accident and 29 patients (63.0%) practiced sport before accident.

The fracture types according to the Letournel classification were 9 anterior columns (20%), 2 trans--verse fractures (4%) , 6 T-types (13%), 20 anterior columns with posterior hemitransverse (43%) and 9 both-columns fractures (20%)[16]. Regarding radiological prognostic factors 28 patients (61%) had at least one prognostic factor, 20 patients (43.5%) with roof impaction, 20 (43.5%) with femoral protrusion, 1 (2%) femoral heads injury, 2 femoral dislocations (4.3%) and 2 floating hips (4.3%)[17-20,24]. The radiological data are summarized in Table 2.

Sixteen patients (35%) had ilioinguinal approach and 30 patients (65%) had AIP approach with 23 modified Stoppa-Cole approach and 7 external window in addition to AIP approach[4-6,16]. Seven patients (15%) had an associated posterior treatment with Kocher-Langenbeck approach[16]. The supra-pectineal plate (Stryker society, Pusignan, France) was used in 27 patients, the infra-pectineal plate (Stryker society, Pusignan, France) in 1 patient and the AO pelvic plate (Johnson and Johnson society, Saint Priest, France) in 19 patients. The mean delay between accident to

Table 1. — Demographic data of the whole series, period 1 and 2

Variables	Overall sample (n=46)	Period 1 (n=23)	Period 2 (n=23)	p value
Sex ratio				
Male (%)	39 (85%)	19 (83%)	20 (87%)	1
Female (%)	7 (15%)	4 (17%)	3 (13%)	1
Age,years (range)	52 ± 18 (20-89)	51 ± 17 (21-89)	54 ± 19 (20-86)	0.56
BMI (kg/m2) (range)	25 ± 3 (17-33)	24 ± 3 (17-33)	25 ± 3 (20-32)	0.66
Mechanism of injury				
High energy (%)	38 (83%)	21 (91%)	17 (74%)	0.24
Low energy (%)	8 (17%)	2 (8.5%)	6 (26%)	0.24
Associated injuries				
Upper limb (%)	11 (24%)	4 (17%)	7 (30%)	0.49
Lower limb (%)	7 (15%)	5 (22%)	2 (8.5%)	0.41
Spine (%)	4 (9%)	2 (8.5%)	2 (8.5%)	1
Brain (%)	2 (4%)	2 (8.5%)	0 (0%)	0.49
Lungs (%)	5 (11%)	2 (8.5%)	3 (13%)	1
Abdomen (%)	4 (9%)	3 (13%)	1 (4%)	0.61
Urogenital (%)	5 (11%)	3 (13%)	2 (8.5%)	1
ISS score (range)	11 ± 5 (3-34)	11 ± 5 (3-25)	10 ± 5 (9-34)	0.55
Fracture pattern according to Letournel				
Anterior column (%)	9 (20%)	6 (26%)	3 (13%)	0.53
Transverse (%)	2 (4%)	0 (0%)	2 (8.5%)	0.53
T-type (%)	6 (13%)	4 (17.5%)	2 (8.5%)	0.53
Anterior column with posterior hemitransverse (%)	20 (43%)	9 (39%)	11 (48%)	0.53
Both column (%)	9 (20%)	4 (17.5%)	5 (22%)	0.53
Surgical approach				
Ilioinguinal (%)	16 (35%)	9 (39%)	7 (30%)	0.54
Modified Stoppa-Cole (%)	30 (65%)	14 (61%)	16 (70%)	0.54
Associated Kocher-Langenbeck (%)	7 (15%)	5 (22%)	2 (9%)	0.41
Clinical preoperative status				
Worker before accident (%)	31 (67%)	18 (78%)	13 (57%)	0.12
Sport activity before accident (%)	29 (63%)	15 (65%)	14 (61%)	0.76
Surgical time, minutes (range)	150 ± 67 (60-300)	163± 59 (90-240)	137 ± 73 (60-300)	0.18
Blood loss, mL (range)	520 ± 202 (100-1200)	505 ± 134 (250-750)	536 ± 235 (100-1200)	0.61
Delay accident-surgery, days (range)	9 ± 6 (3-30)	8 ± 6 (3-30)	9 ± 7 (4-28)	0.76

surgery was 9 ± 6 days (3-30). The mean surgical time for the anterior procedure was 150 ± 67 min (60-300). The mean blood loss for the anterior procedure was 520 ± 202 mL (100-1200).

At mean follow-up of 24 ± 12 months (6-48), 38 patients (83%) were reviewed. The mean PMA was 16 ± 2 (12-18) and mean HHS was 92 ± 10 (70-100). Twenty-four patients (63%) returned to previous work

Table 2. — Radiological data of the whole series, period 1 and 2

Variables	Overall sample (n=46)	Period 1 (n=23)	Period 2 (n=23)	p value
Radiological modifiers				
roof impaction (%)	20 (43%)	9 (39%)	11 (48%)	0.55
acetabular protrusion (%)	20 (43%)	10 (43%)	10 (43%)	1
femoral head injury (%)	1 (2%)	1 (4%)	0 (0%)	1
femoral head dislocation (%)	2 (4%)	0 (0%)	2 (8.5%)	0.48
floating hip (%)	2 (4%)	2 (8.5%)	0 (0%)	0.48
At least one radiological modifier	28 (61%)	14 (61%)	14 (61%)	1
Reduction quality according to Matta				
Anatomical (≤ 1 mm)	28 (61%)	15 (65%)	13 (56%)	0.78
Imperfect (2-3 mm)	8 (17%)	3 (13%)	5 (22%)	0.78
Bad (> 3mm)	10 (22%)	5 (22%)	5 (22%)	0.78

Table 3. — Complications and clinical outcomes of the whole series

Variables	Overall sample (n=46)	Period 1 (n=23)	Period 2 (n=23)	p value
Per operative complications (%)	4 (9%)	0 (0%)	4 (17%)	0.11
veins injury (%)	2 (4%)	0 (0%)	2 (8.5%)	0.49
nerve injury (%)	1 (2%)	0 (0%)	1 (4%)	1
intra-articular screw (%)	1 (2%)	0 (0%)	1 (4%)	1
Post-operative complications (%)	17 (37%)	8 (35%)	9 (39%)	0.76
Infection (%)	5 (11%)	4 (17%)	1 (4%)	0.35
deep venous thrombosis (%)	3(7%)	0 (0%)	3 (13%)	0.23
pulmonary embolism (%)	4 (9%)	2 (8.5%)	2 (8.5%)	1
neurological deficiency (%)	5 (11%)	2 (8.5%)	3 (13%)	1
Re-intervention (%)	6 (13%)	4 (17%)	2 (8.5%)	0.66
Follow-up, months (range)	24 ± 12 (6-48)	32 ± 11 (12-48)	16 ± 6 (6-24)	**< 0.001**
Clinical outcomes	n = 38	n=20	n=18	
PMA (range)	16 ± 2 (12-18)	16 ± 2 (12-18)	16 ± 2 (12-18)	0.89
HHS (range)	92 ± 10 (70-100)	92 ± 11 (70-100)	92 ± 9 (70-100)	0.89
Worker (%)	24 (63%)	14 (70%)	10 (56%)	0.35
Sport activity (%)	23 (61%)	12 (60%)	11 (61%)	0.94
Total Hip Replacement (%)	3 (8%)	2 (10%)	1 (6%)	1
Delay surgery to THR, days (range)	135 ± 91 (75-240)	165 ± 106 (90-240)	NA	NA

NA = Not Applicable

and 23 (61%) returned to the same sport activity (Table 3).

Regarding accuracy of reduction, anatomical reduction (£ 1 mm) was obtained in 28 patients (61%), imperfect reduction (2-3 mm) in 8 patients (17%) and bad reduction (> 3 mm) in 10 patients (22%) (Table 2).

Four per-operative complications (9%) were recorded: 2 patients with vein injuries (4%), 1 nerve injury (2%) and 1 intra-articular screw (2%). Seventeen post-operative complications (37%) were recorded: 5 infections (11%), 3 phlebitis (7%), 4 pulmonary embolism (9%) and 5 neurological deficiencies (11%).

Figure 1. — CT scan axial view of an acetabular fracture (anterior column with posterior hemitransverse) showing bone incarceration into the right extern iliac vein (wight arrow).

A total of 6 revisions surgery were needed (13%). Three patients (8%) received a total hip replacement (THR) with a mean delay from surgery to 135 ± 91 days (75-240) (Table 3). Figure 1 represents one case of external iliac vein injury due to the fracture (bone entrapment into the vein).

Learning curve analysis

Between December 2015 and July 2018 (Period 1), 23 patients were operated by one individual surgeon and were compared to the 23 patients operated on between August 2018 and May 2020 (Period 2). The

Table 4. — Demographic and radiological data comparison between the two periods (learning curve)

Variables	Period 1 (n=23)	Period 2 (n=23)	p value
Age,years (range)	51 ± 17 (21-89)	54 ± 19 (20-86)	0.56
BMI (kg/m2) (range)	24 ± 3 (17-33)	25 ± 3 (20-32)	0.66
Mechanism of injury			
High energy (%)	21 (91%)	17 (74%)	0.24
Low energy (%)	2 (8.5%)	6 (26%)	0.24
ISS score (range)	11 ± 5 (3-25)	10 ± 5 (9-34)	0.55
Fracture pattern according to Letournel			
Anterior column (%)	6 (26%)	3 (13%)	0.53
Transverse (%)	0 (0%)	2 (8.5%)	0.53
T-type (%)	4 (17.5%)	2 (8.5%)	0.53
Anterior column with posterior hemitransverse (%)	9 (39%)	11 (48%)	0.53
Both column (%)	4 (17.5%)	5 (22%)	0.53
Radiological prognostic factors			
roof impaction (%)	9 (39%)	11 (48%)	0.55
acetabular protrusion (%)	10 (43%)	10 (43%)	1
femoral head injury (%)	1 (4%)	0 (0%)	1
femoral head dislocation (%)	0 (0%)	2 (8.5%)	0.48
floating hip (%)	2 (8.5%)	0 (0%)	0.48
Clinical preoperative status			
Worker before accident (%)	18 (78%)	13 (57%)	0.12
Sport activity before accident (%)	15 (65%)	14 (61%)	0.76
Surgical approach			
Ilioinguinal (%)	9 (39%)	7 (30%)	0.54
Modified Stoppa-Cole (%)	14 (61%)	16 (70%)	0.54
Associated Kocher-Langenbeck (%)	5 (22%)	2 (9%)	0.41

Table 5. — Complications, clinical and radiological results comparison between the two periods (learning curve)

Variables	Period 1 (n=23)	Period 2 (n=23)	p value
Surgical time, minutes (range)	163± 59 (90-240)	137 ± 73 (60-300)	0.18
Blood loss, mL (range)	505 ± 134 (250-750)	536 ± 235 (100-1200)	0.61
Delay accident-surgery, days (range)	8 ± 6 (3-30)	9 ± 7 (4-28)	0.76
Reduction quality according to Matta			
Anatomical (≤ 1 mm)	15 (65%)	13 (56%)	0.78
Imperfect (2-3 mm)	3 (13%)	5 (22%)	0.78
Bad (> 3mm)	5 (22%)	5 (22%)	0.78
Per operative complications (%)	0 (0%)	4 (17%)	0.11
Post-operative complications (%)	8 (35%)	9 (39%)	0.76
Re-intervention (%)	4 (17%)	2 (9%)	0.66
Follow-up, months (range)	32 ± 11 (12-48)	16 ± 6 (6-24)	**< 0.001**
Clinical outcomes	n=20	n=18	
PMA (range)	16 ± 2 (12-18)	16 ± 2 (12-18)	0.89
HHS (range)	92 ± 11 (70-100)	92 ± 9 (70-100)	0.89
Worker (%)	14 (70%)	10 (56%)	0.35
Sport activity (%)	12 (60%)	11 (61%)	0.94
Total Hip Replacement (%)	2 (10%)	1 (6%)	1

two groups were comparable regarding age, mechanism of injury, BMI, ISS score, fracture patterns according to Letournel classification, prognosis factors, rate of workers and sporters before accident (Table 4). The two groups were also comparable regarding delay accident to surgery and surgical approaches (Table 4).

No statistical significant differences were found regarding accuracy of reduction, operative time and blood loss (**Table** 5). No statistical significant differences were found regarding per-operative complications, post-operative complications and rate of re-intervention (Table 5). No statistical significant differences were found regarding clinical scores (PMA and HHS), rate of workers and sporters and rate of total hip replacement (Table 5).

Sub-group analysis (ilioinguinal versus AIP approaches, accuracy of reduction and radiological prognostic factors)

When performing univariate analysis to identify factors associated with surgical approach (ilio-inguinal versus modified Stoppa-Cole) fracture patterns distribution showed significant differences (p=0.001) with more anterior column fractures (7/16, 44%) and both columns fractures (5/16, 31%) operated by ilioinguinal approach whereas anterior column with posterior hemitransverse fractures (18/30, 60%) were most often operated by modified Stoppa-Cole approach (p=0.001).

When performing univariate analysis to identify factors associated with accuracy of reduction (anatomical and imperfect reduction versus bad reduction) mean ISS score was significantly higher with bad reduction (14 ± 6 (9-25) versus 10 ± 5 (3-34), p=0.025). Fracture patterns distribution showed significant differences (p=0.01) with more anterior column with posterior hemitransverse fractures (18/36, 50%) associated with good or imperfect reduction and more both columns fractures (5/10, 50%) associated with bad reduction. Regarding prognostic factors a medial protrusion was significantly associated with bad reduction (9/10, 90% versus 11/36, 31%, p = 0.001). The mean operative time was significantly higher with bad reductions (198 ± 60 min (90-300) versus 136 ± 63 min (60-300); p = 0.009). The mean blood loss was significantly higher with bad reductions (670 ± 236 mL (300-1200) versus 476 ± 199 mL (100-750); p= 0.006). Per-operative complications were associated with bad reductions (3/10, 30% versus 1/36, 3%; p = 0.02). At last follow-up, PMA score and HHS were significantly higher with good or imperfect reduction: PMA 17 ± 2 (12-18) versus 15 ± 2 (12-18), p = 0.018; HHS 94 ± 9 (70-100) versus 83 ± 12 (70-100), p = 0.02. Total hip replacement was significantly associated with bad reduction (3/7, 43% versus 0/32, 0%; p = 0.004).

DISCUSSION

This study reports the results of a 5-years learning curve of anterior approaches (ilioinguinal and modified Stoppa-Cole) performed by one single surgeon in a French Trauma Center. Clinical and radiological results of this learning curve are reported and analyzed. With a 9% rate of per operative complications and 37% rate of post-operative complications, an anatomical reduction was obtained in 61% of patients. The modified Stoppa-Cole approach was the most used approach (65% of patients). These findings are different to those reported in the literature because they correspond to a real learning curve. Both ilioinguinal and Stoppa approaches were new approaches for the surgeon. In a recent study comparing ilioinguinal and Stoppa approaches, Shazar et al have compared acetabular fracture reduction quality by the ilioinguinal or the Modified Rives-Stoppa surgical approaches[7]. They have included 225 patients, all of them operated on by the senior surgeon “NS”, 122 using ilioinguinal approach and 103 using the AIP approach. Majority of fracture patterns were both-column fractures (36.4%) followed by anterior column fractures (20.4%). Anatomical reduction was achieved in 75.1% of cases with a mean operative time of 262.4 min. Anatomical reduction was achieved more frequently in patients in the AIP group compared with those in the ilioinguinal group. The operative time was significantly higher with ilioinguinal approaches. No “learning curve effect” i.e. no increasing rate of anatomical reduction chronologically was found. This “learning curve effect” was found regarding operative time[7]. When comparing operative time and reduction with respect to surgical approach (ilioinguinal versus Stoppa) we did not find any significant differences. When comparing operative time and reduction quality chronologically (period 1 versus period 2) we did not find any “learning curve effect” regarding reduction quality and operative time. The same findings were found for blood loss in our study. This could be explained by the fact that “only” 46 patients were operated on the study period (5 years) whereas Shazar et al have operated on 225 patients in a 15-years period. Our results are more realistic and correspond to what a young surgeon who intend to specialize in acetabular fracture surgery should expect to experience. The conclusion that AIP approach possibly achieves higher rate of anatomic reduction compared with the ilioinguinal approach should be discussed. No recommendations about which preferred surgical approach to start with acetabular fracture surgery can be done.

Interestingly, the choice of the surgical approach was associated with the fracture patterns according to Letournel classification because fracture patterns distribution showed significant differences (p=0.001) with more anterior column fractures (44%) and both columns fractures (31%) operated by ilioinguinal approach whereas anterior column with posterior hemitransverse fractures (60%) were most often operated by modified Stoppa-Cole approach (p=0.001). This could be explained by the extension of the fracture line through the coxal bone and the iliac wing in both columns and anterior columns fractures that is supposed to be easily reduced using ilioinguinal approach[25]. Anterior columns with posterior hemitransverse fractures are most often associated with a separation of quadrilateral plate that could be easily reduced using the Stoppa approach[26].

Regarding complications, Shazar et al recorded 13.8% complications without differences due to the surgical approach [7]. This low rate of complications should be related to the experience of this surgeon. A 37% rate of complications was found in our study and seems to be more realistic in the first years of practice of acetabular surgeons. Regarding per operative complications we found a rate of 9% of complications with 2 vein injuries (one obturator vein treated by ligature, one iliac extern vein treated by a vascular bypass). **Figure** 1 shows the vein injury due to the anterior column bone fragment through the iliac extern vein. Before surgery, the injury was incomplete and the patient had no blood loss. Because the bone incarceration into the vein was not identified and because the fracture had involved the quadrilateral plate, a modified Stoppa-Cole approach was performed. To perform surgical exposure, lateral traction applied on the extern iliac vein which completed the veins injury due to the bone entrapment. With more experience, this complication could have certainly be avoided. One iatrogenic nerve injury (2%) of lateral femoral cutaneous nerve and 5 neurological deficiencies (11%) were recorded, without statistical differences according to the surgical approach (ilioinguinal versus AIP Stoppa). According to Kelly et al, the incidence of traumatic nerve injury has changed over time, with an overall rate of injury who dropped from 8% to 6.5% and predominance of lateral femoral cutaneous nerve injury[27]. In our series the majority of neurological deficiencies were sciatic nerve injuries

(3/5, 60%). All of them were preoperative injuries due to the fracture.

Regarding post-operative thrombotic episodes, 3 deep venous thrombosis and 4 pulmonary embolisms were recorded, i.e. 7 thrombotic episodes (15%). This rate is higher than rates extrapolated in a recent literature review. Indeed, Kelly et al have found a stable rate of 4 to 5% of post-operative thrombotic episode[27]. This difference could be explained by the learning curve effect due to the prolonged retraction of vessels during surgery. The knowledge of such complications should allow surgeons to take a special care on retraction and to not use fixed retractors especially in the proximal part of the Stoppa approach (iliac extern vein)[28].

Regarding fracture patterns distribution our findings confirm the marked change in the fracture types described by Kelly et al in a recent literature review [27]. The authors have repeated a meta-analysis originally published by Giannoudis et al in 2005[27,29,30]. They found a significant rise in anterior column-based fractures (anterior column and anterior column with posterior hemitransverse) which are the two most represented fracture types in our series.

If the rate of anatomical reduction, the learning curve effect and the rate of complications expected by a young surgeon in acetabular surgery cannot be extrapolate from the literature, it seems to be also the case for the prognostic factors associated with bad reduction quality. Associated fracture patterns such as both-column fracture and anterior column with posterior hemitransverse were significantly more frequent when a bad reduction was achieved. When bad reduction was achieved, a medial protrusion was more frequent, the operative time was longer with more blood loss. Logically, more post-operative complications were recorded. This findings are not clearly described in big series, meta-analysis or literature reviews[31].

However, the relationship between reduction quality and clinical outcomes remains valid according to the literature. In our series, at last follow-up, PMA score and HHS were significantly lower when a bad reduction was achieved: PMA 17 ± 2 (12-18) versus 15 ± 2 (12-18), p = 0.018; HHS 94 ± 9 (70-100) versus 83 ± 12 (70-100), p = 0.02. In a same way, total hip replacement (THR) was significantly associated with bad reductions (3/7, 43% versus 0/32, 0%; p = 0.004) [27,29-33]. With a total of 3 patients with THR at last follow-up (3/38, 7.9%) in a mean delay after surgery of 135 days our results are comparable to the literature although the higher rate of patients with bad reduction. At last follow-up, 24 patients (24/38, 63%) were able to work at the same place and 23 patients (23/38, 61%) were able to practice sports at the same previous level. These findings show that reduction quality is not the only parameter that should be analyzed to predict clinical outcomes. According to the studies of Verbeek et al and Ovre et al, bad reductions correspond to different radiological results (gap or step) and different locations (roof arc angle or not) with different consequences on clinical outcomes[34,35].

The main limitations of this study are the retrospective design and the relative low rate of patients that have been included. It explains why only univariate analysis could be performed. However only 8 patients were lost to follow-up at 24 months (17%).

CONCLUSION

The systematic inclusion of all patients operated on by the last author during the 5-years inclusion period that corresponds to the first 5-years of experience allows to get a realistic overview of the learning curve. Our results should encourage surgeons to perform acetabular fracture surgery, keeping in mind that such surgical procedures can be challenging, with high rate of complications and difficulty to obtain a systematic anatomical reduction.

REFERENCES

1. Tonetti J, Jouffroy P. Recent progress in the diagnosis and treatment of pelvic ring and acetabular fracture. Orthop Traumatol Surg Res OTSR. France; 2017;103:631-2.
2. Melhem E, Riouallon G, Habboubi K, Gabbas M, Jouffroy P. Epidemiology of pelvic and acetabular fractures in France. Orthop Traumatol Surg Res OTSR. France; 2020;106:831-9.
3. Boudissa M, Francony F, Kerschbaumer G, Ruatti S, Milaire M, Merloz P, et al. Epidemiology and treatment of acetabular fractures in a level-1 trauma centre: Retrospective study of 414 patients over 10 years. Orthop Traumatol Surg Res OTSR. France; 2017;103:335-9.
4. Rives J, Stoppa R, Fortesa L, Nicaise H. Les pièces en dacron et leur place dans la chirurgie des hernies de l'aine. A propos de 65 cas recueillis dans une statistique intégrale de 274 interventions pour hernie [Dacron patches and their place in surgery of groin hernia. 65 cases collected from a complete series of 274 hernia operations]. French. PMID: 4247384. Ann Chir 196822159-71. 1968;
5. Stoppa RE, Rives JL, Warlaumont CR, Palot JP, Verhaeghe PJ, Delattre JF. The use of Dacron in the repair of hernias of the groin. Surg Clin North Am. United States; 1984;64:269-85.
6. Cole J, Bolhofner B. Acetabular fracture fixation via a modified Stoppa limited intrapelvic approach. Description of operative technique and preliminary treatment results. Clin Orthop. 1994;112-123.
7. Shazar N, Eshed I, Ackshota N, Hershkovich O, Khazanov A, Herman A. Comparison of acetabular fracture reduction quality by the ilioinguinal or the anterior intrapelvic (modified Rives-Stoppa) surgical approaches. J Orthop Trauma. United States; 2014;28:313-9.
8. Chesser TJS, Eardley W, Mattin A, Lindh AM, Acharya M, Ward AJ. The modified ilioinguinal and anterior intrapelvic

approaches for acetabular fracture fixation: indications, quality of reduction, and early outcome. J Orthop Trauma. 2015;29 Suppl 2:S25-8.
9. Verbeek, Diederik; Ponsen, KJ; Heijl, Marilene; Goslings, JC. Modified Stoppa approach for operative treatment of acetabular fractures: 10-year experience and mid-term follow-up. Inj 496 1137 - 1140 Elsevier Ltd ISSN 0020-1383. 2018;
10. Moed BR, Israel HA. Which Anterior Acetabular Fracture Surgical Approach is Preferred? A Survey of the Orthopaedic Trauma Association Active Membership. J Orthop Trauma. 2020;34:216-220.
11. Tosun HB, Serbest S, Gümüştaş SA, Uludag A, Celik S. Learning Curve for Surgical Treatment of Acetabular Fractures: A Retrospective Clinical Study of a Practical and Theoretical Training Course. Med Sci Monit Int Med J Exp Clin Res. 2017;23:5218-29.
12. Mardani-Kivi M, Ettehad H, Mirbolouk A, Mousavi MS, Hashemi-Motlagh K, Saheb-Ekhteiari K. Surgical treatment of acetabular fractures and its learning curve. Minerva Ortop Traumatol. 2013;64:319-24. Minerva Ortop Traumatol. 2013;319-24.
13. Matta J, Merritt P. Displaced acetabular fractures. Clin Orthop. 1988;83-97.
14. Haynes SR, Lawler PG. An assessment of the consistency of ASA physical status classification allocation. Anaesthesia. England; 1995;50:195-9.
15. Baker SP, O'Neill B, Haddon WJ, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. United States; 1974;14:187-96.
16. Letournel E. Acetabulum fractures: classification and management. Clin Orthop. United States; 1980;81-106.
17. Anglen JO, Burd TA, Hendricks KJ, Harrison P. The « Gull Sign »: a harbinger of failure for internal fixation of geriatric acetabular fractures. J Orthop Trauma. United States; 2003;17:625-34.
18. Liebergall M, Lowe J, Whitelaw GP, Wetzler MJ, Segal D. The floating hip. Ipsilateral pelvic and femoral fractures. J Bone Joint Surg Br. England; 1992;74:93-100.
19. Gates HS 3rd, Poletti SC, Callaghan JJ, McCollum DE. Radiographic measurements in protrusio acetabuli. J Arthroplasty. United States; 1989;4:347-51.
20. Tonetti J, Ruatti S, Lafontan V, Loubignac F, Chiron P, Sari-Ali H, et al. Is femoral head fracture-dislocation management improvable: A retrospective study in 110 cases. Orthop Traumatol Surg Res OTSR. France; 2010;96:623-31.
21. D'Aubigne RM, Postel M. Functional results of hip arthroplasty with acrylic prosthesis. J Bone Joint Surg Am. United States; 1954;36-A:451-75.
22. Harris W. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969;51:737-755.
23. Borrelli JJ, Ricci WM, Steger-May K, Totty WG, Goldfarb C. Postoperative radiographic assessment of acetabular fractures: a comparison of plain radiographs and CT scans. J Orthop Trauma. United States; 2005;19:299-304.
24. Cannada LK, Hire JM, Boyer PJ, Israel H, Mir H, Halvorson J, et al. Treatment and Complications of Patients With Ipsilateral Acetabular and Femur Fractures: A Multicenter Retrospective Analysis. J Orthop Trauma. United States; 2017;31:650-6.
25. Pohlemann T, Herath SC, Braun BJ, Rollmann MF, Histing T, Pizanis A. Anterior approaches to the acetabulum: which one to choose? EFORT Open Rev. 2020;5:707-12.
26. Collinge CA, Lebus GF. Techniques for reduction of the quadrilateral surface and dome impaction when using the anterior intrapelvic (modified Stoppa) approach. J Orthop Trauma. United States; 2015;29 Suppl 2:S20-24.
27. Kelly J, Ladurner A, Rickman M. Surgical management of acetabular fractures - A contemporary literature review. Injury. Netherlands; 2020;51:2267-77.
28. Tannast M, Keel MJB, Siebenrock K-A, Bastian JD. Open Reduction and Internal Fixation of Acetabular Fractures Using the Modified Stoppa Approach. JBJS Essent Surg Tech. 2019;9:e3.
29. Giannoudis PV, Grotz MRW, Papakostidis C, Dinopoulos H. Operative treatment of displaced fractures of the acetabulum. A meta-analysis. J Bone Joint Surg Br. England; 2005;87:2-9.
30. Tannast M, Najibi S, Matta JM. Two to twenty-year survivorship of the hip in 810 patients with operatively treated acetabular fractures. J Bone Joint Surg Am. United States; 2012;94:1559-67.
31. Ziran N, Soles GLS, Matta JM. Outcomes after surgical treatment of acetabular fractures: a review. Patient Saf Surg. 2019;13:16.
32. Boudissa M, Ruatti S, Kerschbaumer G, Milaire M, Merloz P, Tonetti J. Part 2: outcome of acetabular fractures and associated prognostic factors-a ten-year retrospective study of one hundred and fifty six operated cases with open reduction and internal fixation. Int Orthop. Germany; 2016;40:2151-6.
33. Murphy D, Kaliszer M, Rice J, McElwain JP. Outcome after acetabular fracture. Prognostic factors and their inter-relationships. Injury. Netherlands; 2003;34:512-7.
34. Verbeek DO, van der List JP, Tissue CM, Helfet DL. Predictors for Long-Term Hip Survivorship Following Acetabular Fracture Surgery: Importance of Gap Compared with Step Displacement. J Bone Joint Surg Am. United States; 2018;100:922-9.
35. Øvre S, Madsen JE, Røise O. Acetabular fracture displacement, roof arc angles and 2 years outcome. Injury. 2008;39:922-31.