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ORIGINAL PAPER

Predictors for secondary hip osteoarthritis after acetabular fractures—a pelvic registry study

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Abstract

Purpose Secondary hip osteoarthritis after acetabular fractures requiring total arthroplasty (THA) poses a huge burden on the affected patients as well as health systems. The present study aimed to assess risk factors associated with THA after acetabular fractures based on the data from the German Pelvic Trauma Registry.

Methods Retrospective analysis of 678 acetabular fracture cases without concomitant pelvic ring fracture treated and followed-up between January 2004 and May 2015 at six large trauma centres. Multivariate Cox regression analysis was performed assessing the association of patient/treatment characteristics with THA likelihood at an average follow-up of 2.7 years (range 0.4–9.5 years; SD 1.8 years).

Results Overall, the rate of secondary osteoarthritis was 19.8%. The likelihood for THA increased with 6% per age year (95% CI 1.04–1.09) and with 21% per millimetre subluxation (95%CI 1.09–1.33). This likelihood was 3.54 (95% CI 1.77–7.08) and 3.68 times (95% CI 1.87–7.47) higher if the posterior wall was involved and a contusion and/or impaction of the femoral head was present. Other covariates (sex, ISS, trauma type, AO/OTA and Letournel classification, initial displacement, surgical approach, intra-articular fragments, contusion and/or impaction to the acetabulum, reduction, intervention type, duration of surgery, soft tissue damage, residual fracture step/gap, and prevention of heterotopic ossifications) were not significantly associated ($p > 0.15$).

Conclusions Twenty percent of patients with acetabular fractures require THA. The associated risk factors are patient age, femoral head lesion/subluxation, and involvement of the posterior wall. The identified risk factors support previous research and should be minded when treatment of acetabular fractures is planned.

Keywords German pelvic trauma registry · Secondary hip osteoarthritis · Cox regression model · Acetabular fracture · Secondary hip osteoarthritis

The German Pelvic Trauma Registry of the German Association of Trauma Surgery (DGU)

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Introduction

Secondary osteoarthritis of the hip after acetabular fractures poses a burden for affected patients, the health system, and none the less society [1, 2]. Considering the fact that almost one quarter of patients with acetabular fractures develop a secondary osteoarthritis of the hip [3, 4], it is crucial to know its predictors in order to improve and develop prevention measures and make its treatment as efficient as possible. Only few studies have examined the factors associated with the development of osteoarthritis of the hip after acetabular fractures.

To date, the largest study on predictors for secondary osteoarthritis of the hip after acetabular fractures was published by Tannast et al. [5] in 2012. The authors reported results on a single-surgeon series of 810 patients with operatively treated acetabular fractures. In the 20-year period, 21% of the patients

required a total hip arthroplasty (THA) or a hip arthrodesis. Independent predictors for THA were non-anatomical fracture reduction, where roof impaction, transverse and posterior wall fracture and surgeons in training have been identified as independent risk factors [6]; an age of more than 40 years; anterior hip dislocation; post-operative incongruency of the acetabular roof; involvement of the posterior acetabular wall; acetabular impaction; a femoral head cartilage lesion; initial displacement of the articular surface of ≥ 20 mm; and utilization of the extended iliofemoral approach [5]. Other studies found cartilage damage [7], damage of ligaments and/or bone at the time of injury [8], changes in synovium and synovial fluid [9, 10], increased chondrocyte metabolism [11, 12], unusual stress to the cartilage due to non-anatomic healing [13], and genetic factors [14, 15] to be associated with secondary osteoarthritis of the hip.

Utilizing the data of the German Pelvic Trauma Registry of the German Association of Trauma Surgery (DGU), we aimed to identify the factors associated with the development of osteoarthritis of the hip after acetabular fractures.

Methods

The study was a post hoc analysis of prospectively collected multicentric data in the German Pelvic Trauma Registry. The setup and content of the registry were previously reported [16, 17]. The documentation is based on modern web technology and gathers data in a central database located at the University of Bern in Switzerland (www.ispm.unibe.ch). During the online data entry, various data validation rules apply to ensure the meaningfulness and completeness of each individual dataset.

The registry captures data on various patient and treatment characteristics such as patient age and sex, fracture location, time to treatment, treatment type (conservative or surgical management), type of acetabular fracture, injury patterns, and injury severity. Letournel and AO/OTA classifications are both used for the description of acetabular fractures [18, 19].

Patient sample

Between January 2004 and May 2015, 1636 patients with a surgically treated acetabular fracture and without a concomitant pelvic ring fracture were submitted to the registry from 37 hospitals in two countries: Belgium ($n = 2$) and Germany ($n = 35$). Of these, 678 cases (41.4%) were documented by six large centres (one Belgian and five German) that are following up their patients since 2009. Other hospitals are not yet following up their patients mostly due to a lack in coverage of follow-ups by health insurers. Of the 678 patients, 21 patients (21/678 = 3.1%) were excluded due to age < 18 years, 25 patients (25/657 = 3.8%) due to the implantation of a hip arthroplasty as primary treatment, and six patients (6/657 = 0.9%) due to periprosthetic fractures with already existing hip arthroplasty. The selection resulted in 626 patients who were included in the analysis. Until May 2015, 212 from 626 patients (33.9%) with an acetabular fracture were followed up. The average follow-up interval was 2.7 years (range 0.4–9.5 years; standard deviation [SD] 1.8 years). The following analysis will focus on the 212 followed up patients.

Statistical analysis

Descriptive analyses were performed to display the differences in the distribution of demographic and clinical characteristics of patients with and without THA. Bivariate comparisons were performed using the chi-square test for categorical and the Wilcoxon rank-sum test for continuous covariates. Subsequently, a multivariate Cox regression analysis was carried out with the binary outcome—secondary THA (yes/no). The following covariates were included in the model: patient sex (male, female), patient age at the time of surgery (continuous), ISS (continuous), complex trauma (yes, no; see also below), trauma type (isolated pelvis, multiple injuries, polytrauma), AO/OTA fracture type (A, B, C), Letournel fracture type (anterior column, anterior wall, posterior column, posterior wall, transverse, t-type, transverse + posterior wall, posterior column + wall, anterior column + posterior hemitransverse, both columns, unknown/not classifiable), involvement of the posterior acetabular wall (yes, no), initial displacement (continuous), surgical approach (Kocher-Langenbeck, ilioinguinal, other), intra-articular fragments (yes, no), contusion and/or impaction of the acetabulum (yes, no), contusion and/or impaction of the hip head (yes, no), reduction (yes, no), intervention type (plate, screws, plate + screws, other), duration of surgery (continuous), capsule damage (yes, no), muscle damage (yes, no), residual fracture step on antero-posterior radiographs (continuous), residual fracture gap on antero-posterior radiographs (continuous), anatomical reduction (yes [if both residual fracture gap and step were ≤ 1 mm], no), subluxation (continuous), and prevention of periarticular heterotopic ossification (yes, no). The follow-up interval (continuous) was the time factor in the model. A stepwise selection algorithm was used. The significance level for entering an explanatory variable into the model was set to 0.25 and that for removing an explanatory variable from the model to 0.15. Hazard ratios with 95% confidence intervals (95%CI) were calculated.

A "complex trauma" was originally defined in the registry as type B or C pelvic ring injuries with a major visceral, neurovascular, or soft tissue injury including open fractures, injury of an intrapelvic organ or nerve, and a hemorrhage requiring an intervention, which was then also adopted for acetabular fractures [20, 21].

Additionally, a sensitivity analysis was performed to reveal differences between the followed up ($n = 212$) and non-followed up ($n = 416$) patients.

Level of significance was set to 0.05 throughout the study. All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC, USA).

Results

Sensitivity analysis

Bivariate comparison of patients with (included in the study) and without follow-up (excluded from the study) showed significant differences in patient age, Letournel classification, proportions of surgical approaches, proportions of patients with intra-articular fragments and with prophylaxis of heterotopic ossifications (Table 3). Patients without follow-up were on average five years older, had slightly different proportions of the individual Letournel fractures, as in particular an 8% higher proportion of anterior column + posterior hemitransverse fractures, had a 13% higher proportion of ilioinguinal approach and a lower proportion of other surgical approaches, and had about 22 minutes faster surgery and about 9% less frequent prophylaxis for heterotopic ossification than patients with follow-up (Table 3).

Bivariate comparisons of patients with and without THA

Of the 212 patients, 42 patients (19.8%) underwent THA at an average of 3.1 years (range 0.8–9.1; SD 1.8 years) after acetabular fracture. Bivariate comparisons of patients with a secondary THA and those without a THA showed significant differences in patient sex, AO/OTA and Letournel classifications, proportions of patients with an involvement of posterior wall, surgical approaches, proportions of patients with intra-articular fragments, contusion and/or impaction of acetabulum and femoral head, reduction, capsule and muscle damage, residual fracture gap, and subluxation (Table 1). The patient population with a secondary THA had twice as many female patients, a higher proportion of AO/OTA type A fractures and a lower proportion of AO/OTA type B and C fractures, a lower proportion of anterior column and both column fractures, a higher proportion of posterior wall and posterior column + wall fractures, about twice as frequent involvement of the posterior wall, intra-articular fragments, contusions and/or impaction of acetabulum and femoral head, quality of reduction, soft tissue damage, a higher proportion of Kocher-Langenbeck approach, a larger residual fracture gap and subluxation, and almost 1/5 less frequent achieved anatomical reduction than patients without THA (Table 1).

Multivariate Cox regression model

The results of the model showed four independent significant risk factors for the development of a secondary arthritis of the hip:

- Patient age
- Subluxation
- Involvement of the posterior wall and
- Contusion and/or impaction of the femoral head (Table 2).

According to our results, the likelihood of developing a secondary hip osteoarthritis increases with 6% per year of life and with 21% per millimeter of subluxation (Table 2). Moreover, this likelihood is 3.54 and 3.68 times higher if the posterior wall is involved and a contusion and/or an impaction of the femoral head is present, (Table 2). Other covariates (patient sex, ISS, complex trauma, trauma type, AO/OTA and Letournel fracture type, initial displacement, surgical approach, intra-articular fragments, contusion and/or impaction to the acetabulum, reduction, intervention type, duration of surgery, soft tissue damage, residual fracture step and gap, anatomical reduction, and prophylaxis of heterotopic ossifications) were not significant in the model ($p > 0.15$).

Discussion

Main findings

In our study population, the rate of secondary osteoarthritis of the hip after acetabular fractures was 19.8%. We were able to identify four independent risk factors: age, subluxation, involvement of the posterior wall, and lesion of the femoral head.

Clinical implications

The historical longitudinal study by Judet and Letournel [22] and the recent studies by Tannast et al. [5] and Clarke-Jenssen et al. [23] showed similar rates (18–24%, 21%, and 18%, respectively), despite that these studies had different follow-up intervals. In the so far largest study on risk factors associated with secondary osteoarthritis of the hip after acetabular fractures, Tannast et al. found patient age, femoral head lesion, and involvement of the posterior wall to be significantly associated with the occurrence of secondary osteoarthritis [5] that is in agreement with our results. Moreover, recent studies showed that primary THA is a considerable option for elderly patients and that such patients were more frequently able to ambulate at discharge [24, 25]. Hence, older patients suffering from acetabular fractures requiring surgery should be evaluated for further risk factors and the primary endoprosthetic treatment should be considered.

Table 1 Demographic and clinical characteristics of the patients

Patient characteristics	Categories/values	Units	Secondary THA, $n = 42$ (19.8%)	No THA, $n = 170$ (80.2%)	Bivariate comparison (p value)
Age	Mean ± SD	Years	57.1 ± 14.2	51.9 ± 17.8	0.13
Females		%	*33.3*	*15.3*	*0.008*
Time interval trauma admission	Mean ± SD	Days	2.3 ± 5.9	1.5 ± 2.7	0.81
Time interval admission to surgery	Mean ± SD	Days	4.3 ± 3.7	4.8 ± 5.5	0.18
ISS	Mean ± SD	Points	12.5 ± 8.0	11.7 ± 6.0	0.70
Complex trauma		%	4.8	3.5	0.71
Trauma type	Isolated pelvis	%	47.6	57.0	0.46
	Multiple injuries		35.7	31.8	
	Polytrauma		16.7	11.2	
AO/OTA classification	*A*	%	*54.8*	*33.5*	*0.036*
	B		*31.0*	*41.8*	
	C		*14.3*	*24.7*	
Letournel classification	*Anterior column*	%	*4.8*	*17.1*	*0.007*
	Anterior wall		*2.4*	*1.8*	
	Posterior column		–	*2.4*	
	Posterior wall		*33.3*	*12.4*	
	Transverse		*2.4*	*6.5*	
	t-type		*7.1*	*4.1*	
	Transverse + Posterior wall		*7.1*	*5.3*	
	Posterior column + wall		*9.5*	*5.3*	
	Anterior column + posterior hemitransverse		*14.3*	*21.2*	
	Both columns		*11.9*	*22.9*	
	Unknown/not classifiable		*7.1*	*1.2*	
Involvement of the posterior wall		%	*50.0*	*22.9*	*< 0.001*
Initial displacement	Mean ± SD	mm	12.4 ± 10.7	10.8 ± 9.5	0.43
Contusion and/or impaction of the acetabulum		%	*45.2*	*17.1*	*< 0.001*
Contusion and/or impaction of the femoral head		%	*40.5*	*12.9*	*< 0.001*
Intra-articular fragments		%	*40.5*	*21.8*	*0.013*
Surgical approach	*Kocher-Langenbeck*	%	*50.0*	*31.8*	*0.045*
	Ilioinguinal		*21.4*	*39.4*	
	Other		*28.6*	*28.8*	
Reduction		%	*40.5*	*21.8*	*0.013*
Intervention	Plate	%	23.8	27.7	0.44
	Screws		9.5	15.9	
	Plate + screws		61.9	54.7	
	Other		4.8	1.8	
Duration of surgery	Mean ± SD	min	243 ± 100	216 ± 109	0.08
Capsule damage		%	*47.6*	*18.8*	*< 0.001*
Muscle damage		%	*42.9*	*19.4*	*0.002*
Residual fracture step	Mean ± SD	mm	1.5 ± 2.7	0.7 ± 1.2	0.16
Residual fracture gap	*Mean ± SD*	*mm*	*3.2 ± 5.3*	*1.4 ± 2.1*	*0.019*
Anatomical reduction		%	*38.1*	*62.4*	*0.004*
Subluxation	*Mean ± SD*	*mm*	*1.1 ± 3.3*	*0.1 ± 0.5*	*0.048*
Prevention of heterotopic ossification		%	69.1	69.4	0.96

SD standard deviation. Significant differences are italics

In contrast to Tannast et al. [5], we were not able to confirm acetabular impaction (contusion and/or marginal impaction of the acetabulum), surgical approach, postoperative incongruency of the acetabular roof (residual fracture step and gap), anatomical reduction and initial displacement to be significantly associated with secondary osteoarthritis in the multivariate analysis. This may be due to several reasons. Our model included a larger list of potential predictors than that in the Tannast et al. study. While Tannast et al. dichotomized age into ≤/> 40 years and initial displacement into </≥ 20 mm, we did not group the continuous covariates such as age, initial displacement, duration of surgery, residual step and gap, and subluxation to avoid losing information. Furthermore, regarding the surgical approach, the extended iliofemoral approach was found to be an independent risk factor in the study by Tannast et al., while the authors observed a clear decrease in its utilization until a full stop in 2004. Extended approaches have been

Table 2 Independent predictors for a secondary THA

Covariate	Effect	*p* value	Hazard ratio with 95% CI
Age	Per year	< 0.001	1.06 (1.04–1.09)
Subluxation	Per mm	< 0.001	1.21 (1.09–1.33)
Involvement of the posterior wall	Yes vs. no	< 0.001	3.54 (1.77–7.08)
Contusion and/or impaction of the femoral head	Yes vs. no	< 0.001	3.68 (1.81–7.47)

reserved for more complex injury patterns, but are becoming more and more avoided [26] due to a high level of additional surgical trauma and associated iatrogenic injuries [27]. According to the registry data, this approach is used

Table 3 Comparison of cases with and without follow-up

Patient characteristics	Variable categories	Units	Followed up/included in the study, *n* = 212 (33.9%)	Without follow-up/excluded from the study, *n* = 414 (66.1%)	Bivariate comparison, (*p* value)
Age	*Mean ± SD*	*Years*	*53.0 ± 17.2*	*57.5 ± 19.3*	*0.005*
Females		%	18.9	21.5	0.44
Time interval trauma admission	Mean ± SD	Days	1.6 ± 3.6	2.2 ± 6.1	0.71
Time interval admission to surgery	Mean ± SD	Days	4.7 ± 5.2	6.0 ± 18.7	0.14
ISS	Mean ± SD	Points	11.9 ± 6.4	11.8 ± 5.9	0.25
Complex trauma		%	3.8	3.6	0.92
Trauma type	Isolated pelvis	%	55.2	57.0	0.75
	Multiple injuries		32.6	29.7	
	Polytrauma		12.3	13.3	
AO/OTA classification	A	%	37.7	38.4	0.42
	B		39.6	43.2	
	C		22.6	18.4	
Letournel classification	*Anterior column*	%	*14.6*	*16.2*	*0.023*
	Anterior wall		*1.9*	*0.7*	
	Posterior column		*1.9*	*2.7*	
	Posterior wall		*16.5*	*15.5*	
	Transverse		*5.7*	*2.4*	
	t-type		*4.7*	*5.6*	
	Transverse + Posterior wall		*5.7*	*8.2*	
	Posterior column + wall		*6.1*	*1.9*	
	Anterior column + posterior hemitransverse		*19.8*	*27.8*	
	Both columns		*20.8*	*17.9*	
	Unknown/not classifiable		*2.4*	*1.2*	
Involvement of the posterior wall		%	28.3	25.6	0.47
Initial displacement	Mean ± SD	mm	11.1 ± 9.7	11.3 ± 10.7	0.97
Contusion and/or impaction of the acetabulum		%	22.6	26.6	0.28
Contusion and/or impaction of the femoral head		%	18.4	16.4	0.54
Intra-articular fragments		%	*25.5*	*18.4*	*0.038*
Surgical approach	*Kocher-Langenbeck*	%	*35.4*	*30.4*	*0.004*
	Ilioinguinal		*35.9*	*49.3*	
	Other		*28.8*	*20.3*	
Reduction		%	25.5	23.9	0.67
Intervention	Plate	%	26.9	30.4	0.68
	Screws		14.6	13.5	
	Plate + screws		56.1	52.7	
	Other		2.4	3.4	
Duration of surgery	*Mean ± SD*	*min*	*221 ± 108*	*199 ± 87*	*0.048*
Capsule damage		%	24.5	23.7	0.81
Muscle damage		%	24.1	18.6	0.11
Residual fracture step	Mean ± SD	mm	0.8 ± 1.7	0.9 ± 2.0	0.79
Residual fracture gap	Mean ± SD	mm	1.8 ± 3.1	1.7 ± 2.8	0.15
Anatomical reduction		%	57.6	61.6	0.33
Subluxation	Mean ± SD	mm	0.3 ± 1.5	0.7 ± 3.1	0.17
Prevention of heterotopic ossification		%	*69.3*	*60.6*	*0.032*

SD standard deviation. Significant differences are italics

in only 0.1% of the documented surgical procedures of the acetabulum [16].

We were not able to analyze the risk factor anterior hip dislocation found in the study by Tannast et al. in our model, as it is not part of the documentation in the registry. Instead, hip subluxation was included in the model as a continuous covariate and turned out to be significantly associated with the outcome.

In the bivariate comparison, where only distribution was compared, type of fracture, residual fracture gap, anatomical reduction, and surgical approach were significantly different between the groups with and without secondary osteoarthritis. These effects were not seen in the multivariate Cox regression model, where the effects of each fracture type were analyzed separately to identify their independent effects.

Strengths and weaknesses of the study

One of the major strengths of our study is its multicenter approach, which increases representability of the data and generalizability of the results. Six large centres from two European countries contributed data to this study. However, one relevant limitation in relation to the multicentre approach and non-monitored character of the registry may be potential differences in fracture classification, in radiological diagnostic standards, and in surgical management. The Letournel classification used in the German Pelvic Trauma Registry has good inter-observer reliability for experienced but only moderate inter-observer reliability for unexperienced observers [28]. This limitation is not neglectable despite a multitude of measures applied in the registry to reduce it—a registry documentation guide, classification guidelines, validation rules for the entered data, and biannually held registry user meetings [16].

Although a multitude of patient and treatment characteristics were accounted for in our model, a potential for confounding due to unobserved factors remains. As an example, the six contributing hospitals to the study are tertiary centers, which may have caused referral bias (patients with comorbidities, late referral). However, the vast majority of patients with acetabular fractures are referred to tertiary centres reducing this risk of bias.

Probably, the major limitation of the study is the relatively low follow-up rate of 34%. Despite that the majority of patient and treatment characteristics were not significantly different between patients with and without follow-up, some significant and potentially clinically relevant differences were observed in patient age, distribution of Letournel type fractures, duration of surgery, surgical approach, and prophylaxis of heterotopic ossification (Table 3). Clearly higher follow-up rate studies are still required to reconfirm the identified risk factors.

Conclusions

Despite the continuous improvement of surgical techniques and perioperative care to date still every fifth patient with an acetabular fracture develops secondary osteoarthritis of the hip. According to the multicenter data from the German Pelvic Trauma Registry, the associated risk factors include higher patient age, femoral head lesion, subluxation, and involvement of the posterior wall. The identified risk factors are in agreement with previous research and should be minded when treatment of acetabular fractures is planned.

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Compliance with ethical standards

Conflict of interest Tim Pohlemann is the head of the TK system of the AO Foundation (nonprofit). Those activities are unrelated to the presented topic. All other authors declare that they have no conflict of interest.

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