Factors predicting the failure of Bernese periacetabular osteotomy: a meta-regression analysis

Senthil Nathan Sambandam · Jason Hull ·
William A. Jiranek

Received: 20 June 2008 / Revised: 5 July 2008 / Accepted: 8 July 2008 / Published online: 22 August 2008
© Springer-Verlag 2008

Abstract There is no clear evidence regarding the outcome of Bernese periacetabular osteotomy (PAO) in different patient populations. We performed systematic meta-regression analysis of 23 eligible studies. There were 1,113 patients of which 61 patients had total hip arthroplasty (THA) (endpoint) as a result of failed Bernese PAO. Univariate analysis revealed significant correlation between THA and presence of grade 2/grade 3 arthritis, Merle de'Aubigne score (MDS), Harris hip score and Tonnies angle, change in lateral centre edge (LCE) angle, late proximal femoral osteotomies, and heterotrophic ossification (HO) resection. Multivariate analysis showed that the odds of having THA increases with grade 2/grade 3 osteoarthritis (3.36 times), joint penetration (3.12 times), low preoperative MDS (1.59 times), late PFO (1.59 times), presence of preoperative subluxation (1.22 times), previous hip operations (1.14 times), and concomitant PFO (1.09 times). In the absence of randomised controlled studies, the findings of this analysis can help the surgeon to make treatment decisions.

Résumé Le devenir de l'ostéotomie péri-acétabulaire Bernoise n'est pas évident. nous avons réalisé une méta analyse sur 23 études regroupant 1113 patients sur lesquels 61 patients ont nécessité du fait de l'échec de l'ostéotomie une prothèse totale. une analyse univariable montre une corrélation significative entre la prothèse et la présence d'une arthrose de grade 2 ou 3, le score de Merle d'Aubigne, le score de Harris, l'angle de Tonnies, les modifications de l'angle LCE, les ostéotomies fémorales tardives, la résection d'ossifications. L'analyse multivariable montre, qu'il y a

3,36 fois plus de chances d'avoir une arthrose s'il existe une arthrose de grade 2 ou 3, 12% s'il existe une pénétration articulaire, 1,09% si le score MDS est relativement bas, l'interpénétration articulaire 3,12 fois, le score de Merle d'Aubigné très bas 1,59 fois, une ostéotomie fémorale tardive 1,59 fois, une subluxation préopératoire 1,22 fois, une intervention préalable au niveau de la hanche 1,14 fois, une ostéotomie proximale fémorale concomitante 1,09 fois. Cette analyse permet au chirurgien de prendre des décisions thérapeutiques.

Introduction

Ganz et al. initially described the Bernese periacetabular osteotomy (PAO) in 1988 on 75 hips with dysplasia [7]. In that series, only one patient needed conversion to total hip arthroplasty due to intra-articular joint penetration. Following this report, various authors have reported their experience with Bernese PAO. Most of these reports were retrospective case series with no control group for comparison. Lack of scientific evidence leads to significant controversies with respect to preoperative inclusion criteria. Various authors even considered patients with severe dysplasia, aspherical head, and significant underlying arthritis for PAO [2, 3, 20]. Very few studies attempted to define the factors that could predict the failure of periacetabular osteotomy. Siebenbrock et al., in their retrospective review of 63 patients, showed that age at surgery, presence and grade of osteoarthritis, presence of labral lesion, postoperative acetabular index above 10°, and postoperative anterior centre edge angle less than 40° can negatively influence the outcome of periacetabular osteotomy [19]. Cunningham et al., in their study involving 47 patients undergoing PAO, tried to determine the radiological parameters that would

S. N. Sambandam (✉) · J. Hull · W. A. Jiranek
Department of Orthopaedics, VCUHS,
West Hospital 9th floor, North Wing,
Richmond, VA 23298, USA
e-mail: sam_senthil2002@yahoo.co.in

significantly affect the outcome [5]. They found that such factors as joint space width, joint subluxation, and preoperative osteoarthritis grade can negatively influence the outcome. However, they used revision to total hip arthroplasty (THA) and WOMAC scores as the indicators of failure as opposed to the Merle d'Aubigne score used by Siebenbrock et al. However, none of these studies had adequate patient populations or definite indicators of failure. A well conducted metaanalysis may help better define the factors associated with failure of PAO. However, in the absence of any randomised controlled study on PAO, it was not possible to perform a meta-analysis. Hence, we performed a quantitative systematic analysis by pooling the data presented in all outcome studies published since 1988 and tried to determine the factors that would influence the failure of the procedure in terms of conversion to THA.

Methods and materials

Search strategy

In this study, one of the authors (SSN) initially conducted an extensive literature search to identify all articles reporting outcome following Bernese periacetabular osteotomy. We restricted our search to reports in the English literature. Our primary search was using Medline/Pubmed. We used MESH-term osteotomy with periacetabular (107 total, 15 reviews), Ganz (88 total, 17 reviews), Bernese (39 total, 7 reviews), pelvis (252 total, 14 reviews), dysplasia (701 total, 63 reviews), and acetabular dysplasia (295 total, 31 reviews). We also used other search strategies like EMBASE and CINAHL using the OVID interface and searched other interfaces including EBSCO, Academic Search Premier and Proquest, as well as individual publishers' websites such as MD consult, Science Direct, Lippincott Wilkins and Williams (LWW), Lippincott Ravens, Blackwell Synergy, Wiley Interscience, Taylor and Francis, and Springerlink. We used search terms such as "Bernese osteotomy", "Ganz osteotomy", "periacetabular osteotomy", "pelvic osteotomy", "acetabular dysplasia osteotomy" either alone or in different combinations. Our search identified 26 studies reporting outcome following Bernese periacetabular osteotomy. We retrieved the full text of all the articles to assess eligibility for the study.

Inclusion and exclusion criteria

We included all the studies with follow-up of at least 18 months. We included the studies with less follow-up or duration of follow-up not mentioned if they mentioned total hip arthroplasty in their results. Articles were excluded if they were review articles or letters. We excluded studies if

there was duplication of data. We used the size of the study and study location to identify the redundant data.

Data extraction

Based on the above selection criteria, 23 studies were eligible for our analysis (Table 1). We considered the failure of PAO leading to total hip arthroplasty as the primary end point. Information regarding the study characteristics, preoperative clinical and radiological parameters, postoperative clinical and radiological parameters, intraoperative and postoperative complications and profile of patients undergoing total hip arthroplasty was collected wherever given (Table 2).

Statistical analysis

Descriptive statistics were used to analyse the baseline variables. Pearson's correlation, Spearman's rho, and the chi-square test were used where appropriate for univariate

Table 1 Studies included in this review

Study	Year	Number of hips	Average age	Follow-up	Number of THAs
Ganz et al. [7]	1988	75	29	NR	1
Trousdale et al. [20]	1995	42	37	48	6
MacDonald et al. [12]	1999	13	23	76	0
Murphy et al. [16]	1999	94	29	60	2
Murphy and Millis [15]	1999	130	27	45	5
Ganz et al. [19]	1999	75	29.3	135	13
Crockarell et al. [4]	1999	21	21	38	1
Davey and Santore [6]	1999	70	36.5	NR	0
Trumble et al. [14]	1999	19	30.9	45	2
Matta et al. [13]	1999	66	33.6	48	5
Trumble et al. [22]	1999	123	32.9	51	7
Trousdale et al. [21]	2002	9	34	NR	0
van Bergayk and Garbuz [23]	2002	25	32	33	0
Katz et al. [10]	2005	8	16.5	67	0
Armand et al. [1]	2005	12	35	24	0
Clohisy et al. [2]	2005	16	17.6	NR	0
Pogliacomi et al. [18]	2005	36	35	48	2
Kralj et al. [11]	2005	26	34	144	4
Peters et al. [17]	2006	83	28	46	4
Cunningham et al. [5]	2006	52	28.4	19	5
Hsieh et al. [9]	2006	36	36	24	0
Clohisy et al. [3]	2007	24	22.7	53	0
Garras et al. [8]	2007	58	37.6	66.7	4

THA total hip arthroplasty

Table 2 Variables studied in this review

Character of the study
Author
Year
Location of study
Author had training with Ganz
Preoperative and intraoperative clinical parameters
Age
Duration of follow-up
Number of patients
Preoperative diagnosis
Neurogenic dysplasia
Dysplasia secondary to conditions like Perthes disease, post traumatic, postinfectious, and neurogenic
Patients who had previous surgery to the hip
Harris hip score
Merline De'Aubigne score
Number of patients who needed proximal femoral osteotomy at the time of periacetabular osteotomy to increase the coverage and containment
Preoperative radiological parameters
Severity of dysplasia, especially those with subluxation and false acetabulum
Preoperative arthritis, especially Tonnis grade 2 and grade 3 osteoarthritis
Tonnis angle
Lateral centre edge (LCE) angle
Anterior centre edge (ACE) angle
Postoperative clinical and radiological parameters and complications
Postoperative Harris hip score
Postoperative Merle de' Aubigne score
Patient satisfaction
Patients requiring proximal femoral osteotomy at a later date
Joint penetration
Heterotopic ossification
Removal of implant
Change in Tonnis angle
Change in LCE
Change in ACE

analysis (Table 3). Those variables which showed significant correlation or association in the univariate analysis were included in the multivariate analysis. Multivariate analysis, using a binary logistic regression (meta-regression) model, was performed to assess the influence of heterogeneity of the studies included as well as to predict the explanatory variables.

Results

Our study included 23 outcome reports with 1,113 patients with an average of 48 patients per study. Of these 1,113 patients, 61 patients had total hip arthroplasty as a result of failed Bernese periacetabular osteotomy.

Univariate analysis

Date of publishing

Studies published before 2000 reported significantly more THA (total=42) as compared to the studies after 2000 (total=19).

Age

Average age of patients in the review was 30 (range 22.7–37.6). Average age of the patients who had conversion of PAO to THA was 30.9 as compared to 28.7 in those who had successful PAO. This difference was not statistically significant ($p=0.44$). Also, there was no significant correlation between age and the number of THA ($r=0.19$).

Neurogenic dysplasia and secondary dysplasia

Our analysis failed to show any statistically significant difference in the THA incidence in those studies which included neurogenic dysplasia ($p=0.06$) and other secondary dysplasias ($p=0.33$) as compared to those which did not include these patients. Similarly, there was no correlation between number of patients with either neurogenic dysplasia or other secondary dysplasia and the number of THA.

Number of previous operations

It was generally believed that outcome following PAO is less than satisfactory in patients who had other previous pelvic procedures to treat dysplasia. There were nine studies which mentioned inclusion of patients with previous pelvic surgery. However, our analysis failed to reveal any significant correlation between previous pelvic surgery and failure of PAO ($r=0.50$).

Number of patients in the study and length of follow-up

Number of patients and duration of follow-up showed significant correlation with number of failures in the univariate analysis ($r=0.58$ and 0.50 , respectively). However, multivariate analysis failed to reveal any significant correlation.

Preoperative Merle de'Aubigne score and Harris hip score

Merle de'Aubigne score was used in seven studies and Harris hip score was used in eight studies. Average preoperative Merle de'Aubigne score was 13.25, and average preoperative Harris hip score was 64.5. Low preoperative Harris score failed to reveal any significant correlation to failure of PAO ($r=-0.49$), but low Merle

Table 3 Univariate analysis of variables

Variable	Correlation with number of THA (Pearson's or Spearman's rho)	Correlation with THA needed or not (Binomial variable—chi-square test)	Significance of difference in baseline variables (between studies with failed PAO as compared to studies with no failed PAO [independent <i>t</i> test])
Year	N/A	$p=0.09$	N/A
Age	0.19 ($p=0.36$)	N/A	$p=0.44$
Duration of follow-up	0.50 ($p<0.05$)	N/A	$p=0.18$
Number of patients	0.58 ($p<0.05$)	N/A	$p<0.05$
Neurogenic dysplasia	0.008 ($p=0.97$)	N/A	$p=0.68$
Dysplasia secondary to other conditions	0.16 ($p=0.50$)	N/A	$p=0.95$
Patients who had previous surgery to the hip	0.50 ($p=0.08$)	N/A	$p=0.08$
Preoperative Harris hip score	-0.49 ($p=0.31$)	N/A	$p<0.05$
Preoperative Merle d'Aubigne score	-0.78 ($p<0.05$)	N/A	$p=0.68$
Number of patients who needed proximal femoral osteotomy at the time of periacetabular osteotomy to increase coverage and containment	0.44 ($p=0.07$)	N/A	$p=0.21$
Severe dysplasia especially those with subluxation and false acetabulum	0.87 ($p<0.05$)	N/A	$p=0.29$
Preoperative osteoarthritis: yes or no	N/A	$p<0.05$	N/A
Preoperative arthritis, especially Tonnis grade 2 and grade 3 osteoarthritis	0.56 ($p<0.05$)	N/A	$p<0.05$
Tonnis angle	0.40 ($p=0.10$)	N/A	$p<0.05$
Lateral center edge (LCE) angle	0.29 ($p=0.21$)	N/A	$p=0.15$
Anterior center edge (ACE) angle	0.34 ($p=0.21$)	N/A	$p=0.15$
Postoperative Harris hip score	-0.15 ($p=0.71$)	N/A	$p=0.09$
Postoperative Merle d'Aubigne score	-0.39 ($p=0.38$)	N/A	$p<0.05$
Patients requiring proximal femoral osteotomy at a later date	0.66 ($p<0.05$)	N/A	$p=0.77$
Joint penetration	0.26 ($p=0.21$)	N/A	$p=0.12$
Change in Tonnis angle	0.06 ($p=0.10$)	N/A	$p=0.38$
Change in LCE	-0.32 ($p=0.16$)	N/A	$p<0.05$
Change in ACE	-0.42 ($p=0.11$)	N/A	$p=0.09$

THA total hip arthroplasty, PAO periacetabular osteotomy, N/A not applicable

de'Aubigne score showed significant correlation to failure of PAO in the univariate analysis ($r=-0.78$).

Radiological variables

Preoperative lateral centre edge (LCE) and anterior centre edge (ACE) and postoperative Tonnis angle, LCE, and ACE failed to show any significant correlation to failure of PAO. However, the change in the LCE angle following surgery was significantly more in patients with successful PAO as compared to those in whom PAO failed ($p<0.05$).

Preoperative grade 2/grade 3 arthritis

Our study reveals significant correlation between the conversion to THA and inclusion of Tonnis grade 2 and 3 arthritis patients ($r=0.56$).

Heterotrophic ossification (HO)

Eight studies mentioned postoperative formation of HO. Our analysis reveals no correlation between HO and failure of PAO ($r=0.51$).

Inclusion of patients with subluxation and false acetabulum

Seven studies included patients with subluxation and false acetabulum. Our analysis revealed significant correlation of this variable to failure of PAO ($r=0.87$).

Joint penetration

Intraoperative joint penetration during PAO is considered to be associated with poor outcome by most pelvic surgeons. In contrast, our univariate analysis failed to show any

significant correlation between joint penetration and conversion to THA ($r=0.26$).

Combined PAO with PFO and number of late proximal femoral osteotomies

We postulated that the need for proximal femoral osteotomy either at the time of PAO or at a later time suggests inclusion of a severely dysplastic hip and hence poor outcome. Our analysis revealed significant correlation between the failure of PAO and the need for late PFO ($r=0.66$).

Multivariate analysis

We included all variables which were significant in univariate analysis for the multivariate analysis. We also included nonsignificant variables like secondary dysplasia, combined PAO with PFO, and joint penetration in the multivariate analysis to assess their ability to predict the conversion of PAO to THA. Three different logistic regression models were constructed based on the multicollinearity of the independent variables. None of the explanatory variables studied were able to significantly predict the chance of total hip arthroplasty in a patient undergoing PAO. However, it was evident from the regression model that the odds of having THA increases by 3.36 times with the presence of preoperative grade 2 and grade 3 osteoarthritis, 3.12 times with intraoperative joint penetration, 1.59 times with low preoperative Merle de'Aubigne score, 1.59 times with late PFO, 1.22 with presence of preoperative subluxation, 1.14 times with previous hip surgeries, and 1.09 times with concomitant PFO.

Discussion

Our study shows the importance of various preoperative variables in predicting the failure of PAO. The biggest outcome series to date was reported by Murphy et al. in 1999. In their series involving 130 hips, only five failed [16]. He included patients with grade 2 and grade 3 osteoarthritis in his study, but he failed to mention in his report the proportions of the hips which had advanced osteoarthritis. Further, he used hip score as an outcome variable instead of THA. Siebenbrock et al., in their series of 75 patients, reported 13 THAs [19]; however, they failed to assess the factors leading to the failure of PAO.

Severity of preoperative osteoarthritis and intraoperative joint penetration have been consistently shown by various authors to be associated with poor outcome of PAO [5, 7, 8, 11, 19]. Our analysis further confirms this fact and shows that the odds of THA increases by 3.36 times with severe preoperative OA and 3.12 times with intraoperative joint penetration. Hence, on the basis of current available

evidence and our analysis, we would recommend that surgeons be cautious when recommending Bernese PAO to patients with dysplasia and severe secondary OA changes. Further, surgeons performing PAO should take all measures including cadaveric training to understand the complex 3D orientation of the pelvis, preoperative computerised tomographic scan of each patient, and intraoperative image guidance to avoid intraoperative joint penetration.

Our analysis shows no significant correlation between neurogenic dysplasia and failure of Bernese PAO. This is similar to an exclusive report by MacDonald et al. of Bernese PAO in 13 patients with neurogenic dysplasia [12]. It is a commonly held belief among pelvic surgeons that previous pelvic and hip surgery could adversely affect the outcome of PAO. However, Mayo et al., in their report of 19 PAO patients with previous pelvic surgeries, failed to reveal any such correlation [14]. Similarly, our study failed to show any significant association between previous pelvic operations and failure of PAO in both univariate and multivariate analysis.

In our analysis, we assessed the impact of severity of dysplasia on the outcome of THA. At the start of the analysis, we postulated that severe dysplasia (Severin grade 4 [subluxation] and grade 5 [false acetabulum]) can lead to poor outcome and failure of PAO. Review of the literature revealed that only seven studies have mentioned the preoperative severity of dysplasia, and only four studies mentioned the exact number of patients with severe dysplasia. However, none of these studies exclusively reported the outcome of PAO in patients with severe dysplasia. Most studies failed to report the proportion of patients with severe dysplasia in their study population. Hence, we considered other variables such as need for concomitant PFO or need for PFO at a later date as indicators of severe dysplasia. Our analysis reveals that odds of THA increases by 22% with subluxation, 9% with the need for concomitant PFO, and 54% with late PFO.

We understand that the weight of this study is very limited as there were not any randomised controlled studies on Bernese periacetabular osteotomy in the literature. Further, we included a heterogeneous group of studies in our analysis. Hence we are wary about jumping to any conclusions based on our analysis. However, it has to be agreed that in the absence of randomised controlled trials and well-conducted multicentre studies and limited but confounding evidence, our systematic analysis should help to guide the surgeons and patients in their decision making process.

References

1. Armand M et al (2005) Outcome of periacetabular osteotomy: joint contact pressure calculation using standing AP radiographs, 12 patients followed for average 2 years. *Acta Orthop* 76(3):303–313

2. Clohisy JC et al (2005) Periacetabular osteotomy for the treatment of severe acetabular dysplasia. *J Bone Joint Surg Am* 87(2):254–259
3. Clohisy JC et al (2007) Periacetabular osteotomy for the treatment of acetabular dysplasia associated with major aspherical femoral head deformities. *J Bone Joint Surg Am* 89(7):1417–1423
4. Crockarell J Jr et al (1999) Early experience and results with the periacetabular osteotomy. The Mayo Clinic experience. *Clin Orthop Relat Res* 363:45–53
5. Cunningham T et al (2006) Delayed gadolinium-enhanced magnetic resonance imaging of cartilage to predict early failure of Bernese periacetabular osteotomy for hip dysplasia. *J Bone Joint Surg Am* 88(7):1540–1548
6. Davey JP, Santore RF (1999) Complications of periacetabular osteotomy. *Clin Orthop Relat Res* 363:33–37
7. Ganz R et al (1988) A new periacetabular osteotomy for the treatment of hip dysplasias. Technique and preliminary results. *Clin Orthop Relat Res* 232:26–36
8. Garras DN et al (2007) Medium-term results of the Bernese periacetabular osteotomy in the treatment of symptomatic developmental dysplasia of the hip. *J Bone Joint Surg Br* 89(6):721–724
9. Hsieh PH et al (2006) Image-guided periacetabular osteotomy: computer-assisted navigation compared with the conventional technique: a randomized study of 36 patients followed for 2 years. *Acta Orthop* 77(4):591–597
10. Katz DA et al (2005) Periacetabular osteotomy in patients with Down's syndrome. *J Bone Joint Surg Br* 87(4):544–547
11. Kralj M et al (2005) The Bernese periacetabular osteotomy: clinical, radiographic and mechanical 7–15-year follow-up of 26 hips. *Acta Orthop* 76(6):833–840
12. MacDonald SJ et al (1999) Periacetabular osteotomy in the treatment of neurogenic acetabular dysplasia. *J Bone Joint Surg Br* 81(6):975–978
13. Matta JM et al (1999) Periacetabular osteotomy through the Smith-Petersen approach. *Clin Orthop Relat Res* 363:21–32
14. Mayo KA et al (1999) Results of periacetabular osteotomy in patients with previous surgery for hip dysplasia. *Clin Orthop Relat Res* 363:73–80
15. Murphy SB, Millis MB (1999) Periacetabular osteotomy without abductor dissection using direct anterior exposure. *Clin Orthop Relat Res* 364:92–98
16. Murphy SB et al (1999) Surgical correction of acetabular dysplasia in the adult. A Boston experience. *Clin Orthop Relat Res* 363:38–44
17. Peters CL et al (2006) Early results of the Bernese periacetabular osteotomy: the learning curve at an academic medical center. *J Bone Joint Surg Am* 88(9):1920–1926
18. Pogliacomi F et al (2005) Periacetabular osteotomy. Good pain relief in symptomatic hip dysplasia, 32 patients followed for 4 years. *Acta Orthop* 76(1):67–74
19. Siebenrock KA et al (1999) Bernese periacetabular osteotomy. *Clin Orthop Relat Res* 363:9–20
20. Trousdale RT et al (1995) Periacetabular and intertrochanteric osteotomy for the treatment of osteoarthritis in dysplastic hips. *J Bone Joint Surg Am* 77(1):73–85
21. Trousdale RT et al (2002) Magnetic resonance imaging pelvimetry before and after a periacetabular osteotomy. *J Bone Joint Surg Am* 84-A(4):552–556
22. Trumble SJ et al (1999) The periacetabular osteotomy. Minimum 2 year followup in more than 100 hips. *Clin Orthop Relat Res* 363:54–63
23. van Bergayk AB, Garbuz DS (2002) Quality of life and sports-specific outcomes after Bernese periacetabular osteotomy. *J Bone Joint Surg Br* 84(3):339–343