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High risk of early periprosthetic fractures after primary hip arthroplasty in elderly patients using a cemented, tapered, polished stem

An observational, prospective cohort study on 1,403 hips with 47 fractures after mean follow-up time of 4 years

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Background and purpose — Postoperative periprosthetic femoral fracture (PPF) after hip arthroplasty is associated with considerable morbidity and mortality. We assessed the incidence and characteristics of periprosthetic fractures in a consecutive cohort of elderly patients treated with a cemented, collarless, polished and tapered femoral stem (CPT).

Patients and methods — In this single-center prospective cohort study, we included 1,403 hips in 1,357 patients (mean age 82 (range 52–102) years, 72% women) with primary osteoarthritis (OA) or a femoral neck fracture (FNF) as indication for surgery (367 hips and 1,036 hips, respectively). 64% of patients were ASA class 3 or 4. Hip-related complications and need for repeat surgery were assessed at a mean follow-up time of 4 (1–7) years. A Cox regression analysis was used to evaluate risk factors associated with PPF.

Results — 47 hips (3.3%) sustained a periprosthetic fracture at median 7 (2–79) months postoperatively; 41 were comminute Vancouver B2 or complex C-type fractures. The fracture rate was 3.8% for FNF patients and 2.2% for OA patients (hazard ratio (HR) = 4; 95% CI: 1.3–12). Patients > 80 years of age also had a higher risk of fracture (HR = 2; 95% CI: 1.1–4.5).

Interpretation — We found a high incidence of early PPF associated with the CPT stem in this old and frail patient group. A possible explanation may be that the polished tapered stem acts as a wedge, splitting the femur after a direct hip contusion. Our results should be confirmed in larger, registry-based studies, but we advise caution when using this stem for this particular patient group.

Postoperative periprosthetic fracture (PPF) is a severe complication of hip arthroplasty that may occur months to years after initial surgery. The incidence of PPF is increasing, possibly due to generally widened indications for hip arthroplasty, increased lifespan of patients, a higher number of patients with loose implants, and patients with a revision hip arthroplasty (Lindahl et al. 2005, 2007, Schwarzkopf et al. 2013). The surgical treatment of PPF can be technically demanding and it can be afflicted with a high frequency of complications such as deep infection, dislocation, and intraoperative fractures, which is why repeat surgery is not uncommon (Lindahl et al. 2005, 2006).

PPF rates of between 0.1% and 4% have been reported (Löwenhielm et al. 1989, Lindahl et al. 2005, Cook et al. 2008, Phillips et al. 2013, Schwarzkopf et al. 2013). The variation could possibly be attributed to inhomogeneous patient populations with different follow-up and implants etc. (Löwenhielm et al. 1989, Haddad et al. 1999, Lindahl et al. 2005). Several studies have found risk factors for PPF, e.g. high age, female sex, osteoporosis, previous hip revision procedures, and certain implant types (Sarvilinna et al. 2004, Franklin and Malchau 2007, Cook et al. 2008).

Of the most commonly used cemented implants in Sweden over the years, both the highly polished, tapered and collarless Exeter stem and the satin-finished, flanged Charnley stem have been associated with an increased risk of PPF compared to the often longer and anatomical-shaped Lubinus SP2 (Lindahl et al. 2006), which may contribute to a more homogenous cement mantle. The CPT stem used in this study (Zimmer

Inc., Warsaw, IN, USA) is very similar to the Exeter stem; both are collarless, polished, tapered femoral stems (Yates et al. 2008). Previous reports have shown good long-term results in primary arthroplasty for osteoarthritis (Yates et al. 2008, Burston et al. 2012), but there are no published studies on the rate of PPF associated with the CPT stem. Here we describe the demography and risks of PPF in a consecutive prospective cohort of patients with the CPT stem.

Material and methods

Study setting

This observational, prospective cohort study was performed between 2007 and 2013 at the Orthopaedics Department of Danderyd Hospital in Stockholm, Sweden. Danderyd Hospital is a university hospital affiliated with the Karolinska Institute. It is one of the 5 major emergency hospitals in Stockholm, with a catchment area of approximately 500,000 inhabitants.

Study subjects

The study subjects were identified from an ongoing prospective cohort study on all primary hip arthroplasties performed at the Orthopaedics Department of Danderyd Hospital since 2007. We included patients who underwent hip arthroplasty between 2007 and 2012 using the cemented CPT stem. We excluded patients with inflammatory arthritis or pathological fractures.

Data collection

Using the unique Swedish personal identification number, we collected data on all reoperations prospectively throughout the study period through a combination of searching our in-hospital surgical and medical database, follow-up visits, and searching the Swedish Hip Arthroplasty Register, the Swedish National Patient Register, and the Swedish Death Register. A digital case report form (CRF) was constructed for each patient, and data were registered continuously during the study period. All the patients were followed up until December 2013 or death. The mean follow-up time was 4.1 (1–7) years. Since we used a combination of database searches, medical charts, and follow-ups, no patients were lost to follow-up. We collected patient data including age, sex, cognitive dysfunction (no/probable/certain), and comorbidities registered at primary surgery with the ASA score (Owens et al. 1978). We also registered the indication for surgery (osteoarthritis (OA)/femoral neck fracture (FNF)—including all fracture sequelae), type of arthroplasty (total hip arthroplasty (THA)/hemiarthroplasty (HA)), surgical approach (posterolateral (Moore) or direct lateral (Gammer)), all complications including closed reduction of dislocated hips, and any subsequent open surgery including revision of implants. Digital anteroposterior and lateral radiographs were obtained to evaluate radiographic outcomes and classification of fractures. Periprosthetic fractures were clas-

sified radiographically according to the Vancouver system by Duncan and Masri, as validated by Brady et al. (2000).

The clinical and radiographic outcomes for the patients with PPF were evaluated through a combination of a medical chart review and radiographic analysis at follow-up visits. They were graded roughly as: good in patients with a radiographically healed fracture and no or little impairment in walking; intermediate in patients with a healed fracture but severely impaired walking; and poor in patients with an unhealed fracture and severely impaired walking. Patients who died during hospitalization for the periprosthetic fracture were registered separately.

Implant and surgery

Primary operations were performed either by a consultant orthopedic surgeon or by a registrar with assistance from a consultant. At our institution, a cemented stem is selected for low-to-intermediate-demand patients, 75 years and older, with wide femoral canals and suspected poor femoral bone stock—and for all patients with a displaced femoral neck fracture or those with sequelae after hip fracture. We used the cemented CPT stem (Zimmer Inc., Warsaw, IN), which is a collarless, polished, tapered femoral stem in chrome-cobalt alloy with a 12/14 head taper. The stem is double-tapered and has rectangular proximal geometry. A modular 32-mm cobalt-chrome femoral head was used in all THA patients together with a cemented highly crosslinked polyethylene acetabular component (either a ZCA cup (Zimmer) or a Marathon Cup (DePuy)). A modular unipolar head (Versys Endo (Zimmer)) was used for patients operated with an HA. The majority of patients with a femoral neck fracture were operated with a direct lateral Gammer approach, whereas the posterolateral Moore approach was used in all THA patients with osteoarthritis (Sköldenberg et al. 2010). The same bone cement was used for all patients (Optipac; Biomet, Malmö, Sweden). Intravenous tranexamic acid and prophylactic cloxacillin were administered 30 min before surgery, and the cloxacillin also another 3 times over 24 h postoperatively. Low-molecular-weight heparin was administered for 30 days postoperatively. The patient was mobilized according to a standard physiotherapy program, and full weight bearing with the use of crutches was encouraged. Patients who were operated with the posterolateral approach were instructed to be cautious with flexion in combination with adduction and internal rotation for the first 3 months.

Statistics

The annual incidence rate was calculated by dividing the number of periprosthetic fractures by the total number of years the whole cohort of patients was at risk. We used a Cox proportional hazards model to analyze the risk of sustaining a PPF during the study period. To ensure independent observations, only the first-operated hip was included for patients with bilateral hips. The assumption of proportional hazards

Table 1. Characteristics of subjects. Hips and not individual patients are presented

	No periprosthetic fracture (n = 1,356)	Periprosthetic fracture (n = 47)
Sex [a]		
Male	375 (28%)	12 (26%)
Female	981 (72%)	35 (74%)
Age, years [b]	82 (8)	82 (6)
Height, cm [b]	167 (9)	167 (9)
Weight, kg [b]	67 (14)	69 (13)
ASA category [a]		
1–2	481 (36%)	17 (36%)
3–4	875 (64%)	30 (64%)
Cognitive dysfunction [a]		
No	798 (56%)	32 (68%)
Yes	558 (41%)	15 (32%)
Indication for surgery [a]		
Osteoarthritis	359 (27%)	8 (17%)
Femoral neck fracture	997 (73%)	39 (83%)
Acute fracture	889	36
Sequelae	108	3
Type of arthroplasty [a]		
THA	616 (45%)	20 (43%)
HA	740 (55%)	27 (57%)
Surgical approach [a]		
Posterolateral	536 (40%)	15 (32%)
Direct lateral	820 (60%)	32 (68%)

[a] n (%).
[b] mean (SD).

Table 2. Cox proportional hazard model to evaluate covariates associated with periprosthetic fracture. In this analysis, only the first-operated hip in the study was analyzed and the sample size is therefore 1,357

Covariate	n	Periprosthetic fracture rate (%)	HR (95% CI)	p-value
Sex				
Male	379	3.2	1	
Female	978	3.2	0.9 (0.4–1.6)	0.8
Age				
< 80 years	444	2.3	1	
≥ 80 years	913	3.6	2.0 (1.1-4.5)	0.04
ASA category				
1–2	483	3.2	1	
3–4	874	3.3	1.2 (0.6–2.3)	0.6
Cognitive dysfunction				
No	810	3.8	1	
Yes	547	2.6	0.8 (0.5–1.5)	0.6
Indication for surgery				
OA	348	1.4	1	
Femoral neck fracture	1,009	3.8	4.1 (1.3–12.3)	0.01
Type of arthroplasty				
THA	612	2.8	1	
HA	745	3.5	0.8 (0.4–1.6)	0.6
Surgical approach				
Posterolateral	529	2.7	1	
Direct lateral	828	3.8	1.3 (0.7–2.7)	0.4

was evaluated by a log-minus-log plot for each covariate, where the lines should be parallel if the proportional hazards assumption has been met. Covariates entered into the statistical model were factors that are known to influence the risk of sustaining osteoporosis fractures (sex, age below/above 80 years at primary surgery, ASA category, cognitive dysfunction, and indication for surgery) and surgical factors (type of arthroplasty and surgical approach). The data are presented as hazard ratios (HRs) and the uncertainty estimation with 95% confidence limits (CIs). Any p-value less than 0.05 was considered significant. Statistical analysis was performed using SPSS Statistics software version 22.0 for Mac.

Ethics

The study was conducted in accordance with the ethical principles of the Helsinki Declaration and was approved by ethics committee of the Karolinska Institute (2013/285–31/2).

Results
Study subjects

Of 2,894 THAs from the original cohort, we identified 1,419 hip arthroplasties performed with the CPT stem. After excluding 16 hips with pathological fractures or inflammatory joint disease, 1,403 hips in 1,357 patients were included in the study (379 men and 978 women, mean age 82 (range: 52–102)

years; 367 hips with OA and 1036 with FNF) (Table 1). 511 (38%) of the patients died during the study period. The mortality rate was lower in patients who sustained a periprosthetic fracture than in those who did not, but this difference did not reach statistical significance (p = 0.2, log rank test).

Outcome data

47 PPFs requiring surgery (3.3%) were identified during the study period (2007–2013). The annual incidence rate was 1.1%. The fractures occurred early: at median 7 (3–79) months after primary surgery and the majority (n = 29) within 1 year. All fractures occurred as a result of minor trauma (fall in the same plane). We did not find any evidence that any of these were in fact intraoperative fractures, since none had occurred or dislocated within 1 week of primary surgery. The fracture incidence was higher in patients who were operated due to FNF than in those who were operated for OA: 3.8% vs. 2.2%. It was also generally higher for patients over 80 years of age than for those below 80 years: 3.9% vs. 2.2%. These results were confirmed in the proportional hazards model, where both FNF (HR = 4, CI: 1.3–12) and age over 80 years (HR = 2, CI: 1.1–4.5) increased the risk of sustaining a periprosthetic fracture. Sex, cognitive dysfunction, ASA class, surgical approach, and the type of arthroplasty (THA/HA) had no statistically significant influence on the risk of sustaining a PPF (Table 2).

Table 3. Numbers of hip-related complications leading to reoperation, for the whole cohort and by diagnosis group (for dislocations including closed reduction under general anesthesia). For femoral neck fracture hips, they are also presented separately for THA and HA

| | | | Femoral neck fracture | | |
Hip-related complication	Whole cohort (n = 1,403)	Osteoarthritis (n = 367)	All (n = 1,036)	THA (n = 269)	HA (n = 767)
Periprosthetic fracture	47 (3.3%)	8 (2.2%)	39 (3.8%)	12 (4.5%)	27 (3.5%)
Dislocation	40 (2.9%)	9 (2.5%)	31 (3.0%)	10 (3.7%)	21 (2.7%)
Periprosthetic joint infection	22 (1.6%)	4 (1.1%)	18 (1.7%)	5 (1.9%)	12 (1.7%)
Aseptic loosening (cup)	3 (0.2%)	1 (0.3%)	2 (0.2%)	2 (0.7%)	0 (0.0%)
Other hip- related complication	2 (0.1%)	0 0.0%)	2 (0.2%)	0 (0.0%)	2 (0.3%)

THR: total hip arthroplasty: HA: hemiarthroplasty.

Table 4. Periprosthetic fractures, surgical treatment, and surgical outcome

Vancouver classification	
Vancouver A	1
Vancouver B1	4
Vancouver B2	29
Vancouver B3	1
Vancouver C	12
Surgical treatment	
Open reduction and internal fixation (ORIF)	16 [a]
Stem revision	31 [b]
Surgical outcome [c]	
Good	33
Intermediate	9
Poor	2 [d]
Deceased	3

[a] All type-C fractures, the type-A fracture, and 3 type-B1 fractures were treated with ORIF. In all cases, a femoral locking plate was used.

[b] 1 type-B1 and all type-B2 and -B3 fractures were treated with stem revision. In all stem revisions, the newly implanted femoral stem was reinforced by a femoral locking plate and/or cerclage wires.

[c] The surgical outcome was no different between type-B2 and type-C fractures.

[d] 1 type-C fracture went to non-union and the patient is confined to a wheelchair and cannot be reoperated because of severe comorbidities. 1 type-B1 fracture was initially treated with ORIF. The stem was later revised, and the patient developed periprosthetic joint infection and was treated with excision arthroplasty to heal the infection.

Periprosthetic fractures and other hip-related complications

Periprosthetic fracture was the most common hip-related complication during the study period, followed by dislocations (Table 3). The majority of periprosthetic fracture types were Vancouver type-B2 (n = 29) and complex C-type fractures (n = 12) (Table 4). None of the hips had any radiographic signs of loosening of the stem or periprosthetic osteolysis before fracture. 33 of the fractures had a good outcome according to the previous definition (Table 4).

Discussion

In this prospective cohort study, based on a large cohort of elderly patients with comorbidities who were treated with a cemented, collarless, polished tapered stem, we found a high incidence of early PPF. Indeed, PPF was the most common reason for early repeat surgery at our institution, which contrasts with recent data from the Swedish Hip Arthroplasty Register (SHAR) (Garellick et al. 2011). The SHAR, however, does not capture most patients treated with open reduction and internal fixation without exchange of the implant. Compared to the previous literature on the subject (Table 5), our cohort had a large proportion of patients with femoral neck fracture

Table 5. Accumulated incidence and annual incidence rate in studies on periprosthetic femoral fractures

Study	Selection of patients	No. of hips	No. of PPFs	Years of follow-up	Accumulated incidence (%)	Annual incidence rate (%)
Löwenhielm et al. (1989)	Primary cemented THR	1,442	14	15	2.5%	0–1.2%
Lindahl et al. (2005)	Primary cemented THR	127,744	1,049	22	0.4%	0.045–0.13%
Lewallen and Berry (1998)	Primary arthroplasty	17,579	No data	21	0.6%	No data
Cook et al. (2008)	Primary cemented THR	6,458	124	10	3.5%	No data
Singh et al. (2013)	Primary cemented THR	5,269	115	< 6	2.1%	No data
Brodén et al. (2014)	Primary cemented THR and HA	1,404	47	4	3.3%	1.1%

PPF: periprosthetic fracture; THR: total hip arthroplasty: HA: hemiarthroplasty.

as primary diagnosis and a relatively short follow-up (Lindahl 2007, Cook et al. 2008, Phillips et al. 2013, Singh et al. 2013). However, to our knowledge this is the first large study to deal with the CPT stem and the risk of periprosthetic fracture.

None of the periprosthetic fractures showed evidence of peri-implant osteolysis, and those patients who were classified as Vancouver type-B2 and type-C often had comminuted fractures. Thus, a common denominator in this study, as in other studies, was undoubtedly osteopenia in elderly patients and in those with manifest osteoporosis and femoral neck fracture (Sarvilinna et al. 2004, Lindahl et al. 2005, Franklin and Malchau 2007, Cook et al. 2008). We also suspect the choice of implant, since it appears that the polished tapered stem, designed to subside in the cement mantle with axial load, may in fact act as a wedge, breaking the femur after a direct hip contusion—an injury mechanism already discussed by Sarvilinna et al. (2004). This injury mechanism for all polished, tapered stems (including the Exeter stem) means that as soon as a periprosthetic fracture occurs, the stem is by definition loose (i.e. a B2-type fracture). In a small in vitro study on cadavers, Thomsen et al. (2008) showed that fracture patterns in cemented hip stems correspond to the more complex Vancouver type-C fracture, a finding which does not contradict our results. 12 out of 47 fractures in our study were type-C fractures.

There has been one study in which the CPT stem was used in patients with a femoral neck fracture. Avery (2011) presented a follow-up of a randomized controlled trial comparing THA with HA for the treatment of FNF. They had 1 late-occurring PPF in their small study set (of 47 patients) and 1 revision due to massive subsidence of the stem. Finding only 2 revisions on the femoral side, they drew the conclusion that the CPT stem was suitable for either procedure. The small sample size and the relatively young age of the patients (mean 75 years at inclusion as compared to 82 years in our study) make comparisons difficult. One could also argue that a large, prospective observational study such as ours, where we included all patients in a certain time period, better reflects the true clinical behavior of the stem with regard to PPFs.

Previous epidemiological studies have shown that the straight Exeter stem (Stryker Inc., Kalamazoo, MI), which resembles the CPT stem (with the exception that the CPT has a more rectangular proximal cross-sectional shape), is associated with a higher risk of PPF than the anatomical Lubinus SP2 stem (Lindahl et al. 2005, 2006). As in our study, radiographs were not analyzed for risk factors. These studies did not include any radiographic evaluation, so it is difficult to take the fracture patterns into account and assess whether these straight stems were initially either misaligned or afflicted with a poor cement mantle distally at the tip. Even though we could not find a statistical association between PPF and the direct lateral approach, anteroposterior malalignment in the sagittal plane is probably more common with straight stems together with the Gammer approach due to insufficient poste-

rior resection of the femoral neck, followed by an entry point that is too far forward (Garellick et al. 1999, Lindahl et al. 2006). This mechanism may explain why PPFs in CPT stems with endosteal contact of the pointy tip are more prevalent in FNF patients (Hank et al. 2010, Macpherson et al. 2010), an effect that may be only partly overcome by stem centralizers—which we used in all our patients (Breusch et al. 2001). Conversely, the Lubinus SP 2 stem requires a more distal femoral neck osteotomy than the Exeter/CPT, which exposes the femoral canal, and is anatomically shaped. This may give better alignment and more homogenous cement mantles. The collared Lubinus SP2 stem also shows extremely low distal migration, as measured by radiosteremetry (Wierer et al. 2013), and all of these contributory factors may reduce the risk of PPF—especially in FNF patients. Longer cemented stems anchored distally in harder diaphyseal bone might conceivably reduce this risk further, which is supported by biomechanical studies showing that shorter stems have reduced resistance to torque forces (Bishop et al. 2010, Morishima et al. 2014). The standard length (150 mm) of the Exeter and CPT stems is the same as for the Lubinus SP2 stem, which alone might explain the previous registry-based results where stem length was not taken into account either. In a large registry-based study that did not include the CPT stem, Singha et al. (2013) found that ASA class 3 or higher and female sex was associated with a higher risk of PPF. We have been unable to verify these results in our study, possibly because of the smaller size of our sample.

Strengths and limitations

The strengths of our study include its prospective study design, the completeness of data on the incidence of early, surgically treated PPF, and the homogeneity of implant choice. The weaknesses are the single-center design, the relative short follow-up time, and the lack of radiographic analysis. Another limitation of the study is that we only recorded reoperations and not conservatively treated type-A fractures. The incidence rate of PPF increases with time (Lindahl et al. 2005), which is why longer follow-up is needed to verify the true fracture incidence associated with this implant.

Conclusion

In octogenarian patients with high comorbidity and osteoporosis, we found that the cemented, straight, polished, tapered stem was associated with a high rate of early periprosthetic fractures requiring major surgery. Our results should be confirmed in larger, registry-based studies, but we advise caution in using the CPT stem for this particular patient group.

No competing interests declared

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