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Abstract	**Aims** This study aimed to evaluate implant survival of reverse hybrid total hip arthroplasty (THA) at medium-term follow-up. **Patients and Methods** A consecutive series of 1082 THAs in 982 patients with mean follow-up of 7.9 years (5 to 11.3) is presented. Mean age was 69.2 years (21 to 94). Of these, 194 (17.9%) were in patients under 60 years, 663 (61.3%) in female patients and 348 (32.2%) performed by a trainee. Head size was 28 mm in 953 hips (88.1%) or 32 mm in 129 hips (11.9%). Survival analysis was performed and subgroups compared using log rank tests. **Results** Ten-year survival (122 hips at risk) was 97.2% (95% confidence interval (CI) 95.77 to 98.11) for all-cause revision. There was no difference in survival by age (p = 0.50), gender (p = 0.78), head size (p = 0.63) or surgeon grade (p = 0.36). No acetabular components underwent revision for aseptic loosening in the entire series. Four (0.4%) aseptic stem failures occurred early at a mean of 2.5 years (0.6 to 4.8) and were associated with age under 60 years (p = 0.015). There was no difference in survival by gender (p = 0.12), head size (p = 0.43) or surgeon grade (p = 0.77) for stem revision. **Conclusion** This is the largest reported study into reverse hybrid THA and it confirms successful outcomes, irrespective of age, gender, head size and surgeon grade. Cite this article: *Bone Joint J* 2018;100-B:??-??.

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Reverse hybrid total hip arthroplasty (THA), using a cemented acetabular component and a cementless femoral stem, offers significant theoretical benefits over other forms of THA but is rarely performed, representing only 2.5% of all THAs recorded by the National Joint Registry (NJR) for England, Wales, Northern Ireland and the Isle of Man.[[1]] Cemented all-polyethylene acetabular components have excellent reported rates of survival in the long term, they are inexpensive, allow local antibiotic delivery through bone cement and provide reliable fixation in osteoporotic or pathological bone.[[2]] The use of cementless stems allows shorter operating times than can be achieved with cemented stems, eliminates the risk of bone cement implantation syndrome and achieves reliable long-term fixation in younger patients.[[3-5]] However, cemented acetabular components do not allow the use of alternative bearing surfaces, take longer to perform, have a more demanding surgical technique when compared to cementless components; cementless stems are more expensive than cemented implants and have a greater risk of periprosthetic fracture (PPF).[[6,7]]Whilst registry data confirms low rates of revision for reverse hybrid THA,[[1,8,9]] there are very few clinical studies of this form of THA. Those which do exist are generally small, with short follow-up times and use a limited range of bearing surfaces, i.e. ceramic on ultra-high molecular weight polyethylene.[[10-12]]

The primary objective of this study was to determine ten-year implant survival in a large consecutive series of adult patients undergoing reverse hybrid THA with revision surgery for any indication as the endpoint. The secondary objective was to determine the effect of age, gender, femoral head size and grade of surgeon on implant survival.

Patients and Methods

This is a retrospective series of consecutive reverse hybrid THAs performed at a single institution (between December 2005 and March 2012) by a number of surgeons. All patients with severe, functionally disabling hip pain were considered suitable for reverse hybrid THA except those with previous radiotherapy treatment which may have compromised stem integration. The indications for surgery and baseline demographic details are provided in Table I. All adult patients undergoing primary reverse hybrid THA for any indication were included in this study as long as they had at least five years of follow-up. All patients received the Corail cementless femoral component (DePuy Synthes, Leeds, United Kingdom) and either the Elite ultra-high molecular weight polyethylene (UHMWPE) or Marathon cross-linked polyethylene (XLPE) flanged acetabular component (both DePuy Synthes, Leeds, United Kingdom). To reduce heterogeneity, six hips were excluded as they were performed using different implants from these. Data were collected using local databases and radiographs. Data collected included age, gender, Dorr femoral classification,[[13]] surgical factors and implant details. Postoperative clinical details were collected on complications (local and systemic) and revision surgery (date and indication). Individual surgeon NJR records were cross-referenced with the original dataset to identify any revisions carried out at other institutions; none were found. This study was discussed with the local ethics committee and we were informed that formal ethical approval was not necessary.

[[TblCap]]**Table I.** Baseline clinical and demographic characteristics

Characteristics	
Hips, n (patients)	1082 (982)
Mean age, yrs (range)	69.2 (21 to 94)
Under 60 yrs (%)	194 (17.9)
Over 60 yrs (%)	888 (82.1)
Mean length of follow-up (range)	7.88 (5 to 11.3)
Right sided THA (%)	594 (54.9)
Number of surgeons	18
Grade of surgeon (%)	
Consultants	734 (67.8)
Trainee	348 (32.2)
Indication for surgery (%)	
Primary osteoarthritis	985 (91)
Acute NOF fracture	19 (1.7)

Osteonecrosis	17 (1.6)
Post-traumatic arthritis	16 (1.5)
Rheumatoid arthritis	14 (1.3)
Hip dysplasia	10 (0.9)
Nonunion of hip fracture	10 (0.9)
Paget's disease	5 (0.5)
Perthes disease	3 (0.3)
Slipped upper femoral epiphysis	2 (0.2)
Pathological fracture	2 (0.2)
Previous sepsis	1 (0.1)
Femoral head tumour	1 (0.1)
Dorr femoral classification (%)	
Type A	357 (33.0)
Type B	465 (43.0)
Type C	260 (24.2)
Acetabular polyethylene component (%)	
Marathon (XLPE)	667 (61.6)
Elite (UHMWPE)	415 (38.4)
Corail femoral component (%)	
Collared	753 (69.6)
Collarless	329 (30.4)
Femoral head size (%)	
28 mm	953 (88.1)
32 mm	129 (11.9)
Femoral bearing surface (%)	
Metal	832 (76.9)
Ceramic	250 (23.1)

[[TblNote]]THA, total hip arthroplasty; NOF, neck of femur; XLPE, cross-linked polyethylene; UHMWPE, ultra-high molecular weight polyethylene

All patients had postoperative radiographs performed at each outpatient follow-up visit. As per local policy, only anteroposterior radiographs are taken for routine follow-up in order to limit ionizing radiation exposure. Latest radiographs were reviewed independently by two fellowship trained arthroplasty surgeons (SJ and MM). Acetabular radiolucent lines (RLLs) were recorded according to the DeLee and Charnley zones[[14]] and classified according to the system of Hodgkinson et al;[[15]] femoral RLLs were classified by Gruen zone.[[16]] Migration of implants, or progressive RLLs on serial radiographs were taken to indicate loosening. Any heterotopic ossification present was classified by Brooker grade.[[17]]

All THAs had preoperative templating and were performed through a posterior approach using a standardized technique described as follows. Antibiotics are given preoperatively in all cases. Following exposure of the acetabular rim and sequential reaming to bleeding subchondral bone, any cysts are curetted and between five and ten keyholes are drilled into the ilium, ischium and pubis. An acetabular component 8 mm smaller in outer diameter than the last reamer is selected and the flange is trimmed to ensure a seal for cement pressurization. Half of the 40 g mix of Palacos R+G (Heraeus Medical, Wehrheim, Germany) is pressurized into the acetabulum using a proprietary pressurizer. Finger-packing of cement into the keyholes is then performed followed by insertion and pressurization of the remaining cement. Final insertion of the acetabular component using the mechanical alignment guide for inclination and transverse acetabular ligament for anteversion[[18]] is performed before the residual cement is cleared from the rim.

The Corail femoral component is implanted using the manufacturer's standard technique.[[19]] Sequential broaching is performed until axial and rotational stability is achieved and the hip is trialled to ensure restoration of length and offset. Following a satisfactory trial, if a collared stem is to be used, the calcar is reamed. After removal of the last broach, the calcar is inspected for signs of fracture in which case a single cerclage wire is used to prevent propagation. The stem is impacted into the canal and the appropriate femoral head is inserted before reduction and closure. Posterior transosseous repair of the hip capsule and short external rotators is performed in all cases.

Patients were mobilized fully weight-bearing, except in cases of intraoperative fracture. Hip precautions were followed to reduce the risk of dislocation. All patients had chemical and mechanical thromboprophylaxis for six weeks unless contra-indicated. Patients were reviewed at three months, one year, five years and then every five years postoperatively.

Overall, 1082 reverse hybrid THAs (982 patients) were identified (Fig. 1) with a mean follow-up of 8.2 years (5 to 11.3). In all, 91 patients had sequential bilateral THAs and nine patients had simultaneous bilateral THAs. Mean patient age was 69.2 years (range, 21 to 94) and 663 (61.3%) procedures were performed on female patients. By the end of the follow-up period, 212 patients, (226 hips, 21.5%) had died. One of these patients died following postoperative pneumonia but the remaining deaths were not attributable to surgery. No patients were lost to follow-up. A total of 18 different surgeons performed the operations and 348 (32.2%) of these were performed by a trainee. End-stage osteoarthritis was the most common indication for surgery (985 hips, 91%).

[[Fig 1]]

[[FigCap]]Flow chart showing application of eligibility criteria (THA, total hip arthroplasty; UHMWPE, ultra-high molecular weight polyethylene; XLPE, cross-linked polyethylene)

The details of the components implanted are reported in Table I. Collared stems were used in 753 (69.6%) hips and were used more commonly later in the series following reports of early subsidence with collarless stems.[[20]]

Our primary outcome measure was implant survival with revision for any reason as the endpoint. As a secondary analysis, we compared survival on the basis of age (dichotomised into patients over and under 60 years of age), gender, head size (28 mm versus 32 mm) and surgeon grade (consultant versus trainee).

Statistical analysis

Baseline characteristics were reported as means for continuous variables and percentages for categorical variables. Survival analysis was performed with revision for any reason as the endpoint; life tables and Kaplan–Meier curves were produced. Subgroup analyses to investigate the association between age, gender, head size and grade of surgeon on implant survival were evaluated using log rank tests. Chi-squared or Fisher’s exact tests were used to assess the effect of head size, gender and surgeon grade on dislocation and whether the presence of RLLs varied by polyethylene type (UHMWPE versus XLPE) or head size (28 mm versus 32 mm). Analyses were performed using Stata 13.1 software (StataCorp LP, College Station, Texas) and the level of significance was set at $p < 0.05$.

Results

Implant survival

At ten years, implant survival (122 hips at risk) was 97.2% (95% confidence interval (CI) 95.8 to 98.1) with all-cause revision as the endpoint (Table II, Fig. 2). The most common indication for revision (Table III) was dislocation (12 hips in 12 patients, 1.1%) followed by infection (four hips in four patients, 0.4%, all of whom underwent two stage revision), femoral stem loosening (four hips in four patients, 0.4%), postoperative femoral PPF (three hips in three patients, 0.3%), leg-length discrepancy (one hip, 0.1%) and femoral perforation (one hip, 0.1%).

[[TblCap]]**Table II.** Life table survival analysis for all-cause revision

Interval (yrs)	Number at risk	Revisions	Withdrawn	Survival (%)	95% confidence interval (%)
0 to 1	1082	6	23	99.44	98.76 to 99.75
1 to 2	1053	6	17	98.87	98.02 to 99.36
2 to 3	1030	2	23	98.67	97.77 to 99.21
3 to 4	1005	2	25	98.48	97.52 to 99.06
4 to 5	978	2	30	98.27	97.27 to 98.91
5 to 6	946	2	214	98.04	96.97 to 98.73
6 to 7	730	3	170	97.58	95.77 to 98.40
7 to 8	557	2	160	97.17	95.77 to 98.11
8 to 9	395	0	151	97.17	95.77 to 98.11
9 to 10	244	0	122	97.17	95.77 to 98.11
10 to 11	122	0	115	97.17	95.77 to 98.11

[[Fig 2]]

[[FigCap]]Kaplan–Meier survival analysis curve for all-cause revision (CI, confidence interval).

[[TblCap]]**Table III.** Details of patients who underwent revision surgery

Age at surgery (yrs)	Time to revision (yrs)	Gender	Grade of surgeon	Indication	Femoral stem (Corail)	Head size (mm)	Femoral bearing surface	Acetabular component type	Indication
78	1.61	Male	Consultant	OA	KS12	28	Metal	UHMWPE	Instability
80	7.80	Female	Consultant	OA	KS9	28	Metal	UHMWPE	Periprosthetic fracture
58	4.78	Male	Consultant	OA	KLA9	28	Metal	UHMWPE	Aseptic loosening stem
75	6.49	Female	Consultant	OA	KLA10	28	Metal	UHMWPE	Instability
70	6.28	Female	Consultant	OA	KLA11	28	Metal	UHMWPE	Instability
70	1.04	Female	Consultant	OA	KA10	28	Metal	UHMWPE	Instability
81	6.49	Female	Consultant	OA	KHO10	28	Metal	UHMWPE	Instability
64	1.86	Male	Trainee	OA	KLA14	28	Metal	UHMWPE	Infection
53	0.01	Female	Consultant	NOF	KA9	28	Ceramic	UHMWPE	Femoral stem

									malposition
76	5.28	Female	Trainee	OA	KA11	28	Metal	UHMWPE	Instability
52	1.02	Female	Consultant	OA	KA11	28	Metal	XLPE	Instability
63	1.46	Female	Trainee	OA	KA11	28	Ceramic	XLPE	Infection
56	1.15	Male	Consultant	OA	KHO10	28	Metal	XLPE	Infection
73	2.06	Female	Trainee	OA	KS9	28	Metal	XLPE	Aseptic loosening stem
65	0.24	Female	Consultant	OA	KA11	28	Metal	XLPE	Instability
66	0.39	Female	Consultant	NOF	KA14	28	Metal	XLPE	Instability
61	7.24	Male	Consultant	OA	KA10	28	Metal	XLPE	Instability
77	3.18	Male	Consultant	OA	KHO10	28	Metal	XLPE	Periprosthetic fracture
59	2.39	Male	Consultant	OA	KA8	28	Ceramic	XLPE	Aseptic loosening stem
65	0.00	Female	Consultant	OA	KA8	28	Metal	XLPE	Infection
83	0.04	Female	Trainee	Post-traumatic OA	KS11	28	Metal	XLPE	Instability
80	3.85	Male	Consultant	OA	KHO12	32	Metal	XLPE	Periprosthetic fracture
71	4.16	Female	Trainee	OA	KA12	28	Metal	XLPE	LLD
55	0.61	Male	Consultant	OA	KLA9	32	Ceramic	XLPE	Aseptic loosening stem
85	5.25	Male	Consultant	OA	KS8	28	Metal	XLPE	Instability

[[TblNote]]OA, osteoarthritis; NOF, neck of femur fracture; KS, collarless, standard offset; KA, collared, standard offset; KLA, collared, lateralized stem; KHO, collared, high offset; UHMWPE, ultra-high molecular weight polyethylene; XLPE, crosslinked polyethylene; LLD, leg-length discrepancy

No acetabular components in the entire series required revision for aseptic loosening. Four femoral stems (four patients) had aseptic loosening and were revised at a mean of 2.5 years (range, 0.6 to 4.8). These were all attributable to undersizing. Three of these stems were collared and migrated into a varus position with the collar pivoting on the medial calcar (Fig. 3). Progressive RLLs were seen in zones 1, 5 and 7.[[16]] The remaining stem was collarless and subsided distally-with progressive RLLs seen in zones 1 and 7.[[16]] A summary of the stem failures is presented in Table IV.

[[Fig 3]]

[[FigCap]]Postoperative pelvic radiograph showing a reverse hybrid total hip arthroplasty (left hip) with an undersized collared stem (a) and aseptic loosening by two years with varus stem migration and calcar remodelling (b).

[[TblCap]]**Table IV.** Summary of patients with femoral aseptic loosening

Age at	**Gender**	**Primary**	**Dorr**	**Femoral**	**Undersized**	**Collar**	**Mode of failure**	**Progressive**	**Time to**

primary surgery (yrs)		indication	classification of femur	stem size (Corail)				radiolucent lines	revision (y
58	Male	OA	A	KLA9	Yes	Yes	Varus migration	Zone 1, 5,7	4.78
73	Female	OA	B	KS9	Yes	No	Distal subsidence	Zone 1,7	2.06
59	Male	OA	A	KA8	Yes	Yes	Varus migration	Zone 1, 5,7	2.39
55	Male	OA	A	KLA9	Yes	Yes	Varus migration	Zone 1, 5,7	0.61

[[TblNote]]OA, osteoarthritis; KS, collarless, standard offset; KA, collared, standard offset; KLA, collared, lateralized stem

Dislocation occurred in 20 hips (20 patients, 1.8%), all of which had 28 mm heads. Of these, eight were successfully treated with closed reduction but 12 eventually had revision surgery due to recurrent instability. A posterior lip augmentation device (DePuy Synthes, Leeds, United Kingdom) was used successfully in 11 hips; one had further instability and was re-revised using a dual mobility acetabular component. No stems revisions were required.

Intraoperative femoral fracture occurred in 11 hips (11 patients, 1%), none of which required revision. A further three PPFs occurred postoperatively and required revision. There were no intraoperative or postoperative acetabular periprosthetic fractures. All complications of surgery are given in Table V.

There was no difference in overall survival according to age ($p = 0.50$), gender ($p = 0.78$), head size ($p = 0.63$) or surgeon grade ($p = 0.36$, log rank tests). There was also no difference in survival by gender ($p = 0.12$), head size ($p = 0.43$) or surgeon grade ($p = 0.76$, log rank tests) for stem revision for aseptic loosening. However, patients under 60 years (194 hips in 178 patients, 17.9%) were more likely to undergo stem revision for aseptic loosening than patients over 60 years ($p = 0.015$, log rank test). There was no statistically significant association between dislocation rate and gender ($p = 0.54$), head size ($p = 0.08$) or surgeon grade ($p = 0.07$, Fisher's exact tests).

[[TblCap]]**Table V**. Surgical complications

Complication	Hips, n (patients, hips %)	Management
Dislocation	20 (20, 1.8)	12 revised due to recurrent dislocation; 8 treated nonoperatively

Intraoperative periprosthetic fracture	11 (11, 1)	8 immediate internal fixation; 3 treated nonoperatively
Periprosthetic joint infection	4 (4, 0.4)	2 acute cases had 2-stage revision after failed debridement, modular implant exchange and antibiotic therapy; 2 chronic cases had 2-stage revision
Stem loosening	4 (4, 0.4)	All revised
Venous thromboembolism	3 (3, 0.3)	All treated pharmacologically
Sciatic nerve palsy	1 (1, 0.1)	Observation with partial resolution
Femoral nerve palsy	1 (1, 0.1)	Observation with complete resolution
Femoral perforation	1 (1, 0.1)	Revised
Pneumonia	1 (1, 0.1)	Intensive care treatment but patient died
Total	**46 (46, 4.3)**	

Radiographic analysis

Latest radiographs at a mean follow-up of 6.6 years(range, 4.5 to 10.5) were available for review in 1050 THAs (97%, 946 patients). Overall, RLLs were present in 118 hips (112 patients, 10.9%). Acetabular RLLs were present in 82 hips (77 patients, 7.6%) and femoral RLLs in 36 hips (35 patients, 3.3%), (Table VI). Of the acetabular RLLs, two progressed and both were associated with infection. Except for the four femoral components revised for infection, no other stem demonstrated progressive RLLs. There was no statistically significant association between the presence of RLLs and type of polyethylene (p = 0.13) or head size (p = 0.25, chi-squared tests). Heterotopic ossification was observed in 43 hips (40 patients, 3.9%), and were Brooker grade[[17]] one in 19 hips (1.8%), grade two in seven hips (0.6%), grade three in ten hips (0.9%) and grade four in seven hips (0.6%).

[[TblCap]]**Table VI.** Radiolucent lines (RLLs)

Implant	Classification	Hips, n (%)
Acetabular component	Grade 0 (none)	1000 (92.4)
	Grade 1 (zone 1)	66 (6.1)
	Grade 2 (zone 1 and 2)	14 (1.3)
	Grade 3 (all zones)	2 (0.2)
	Grade 4 (migration)	0
	Total cups with RLLs	**82 (7.6)**
Femoral stem	None	1046 (96.7)
	Zone 1	19 (1.8)
	Zone 1 and 7	14 (1.3)
	Zone 1, 7 and others	3 (0.3)
	Total stems with RLLs	**36 (3.3)**

Discussion

Our results indicate high rates of implant survival following reverse hybrid THA, irrespective of age, gender, femoral head size and surgeon grade. This is the largest reported study on the outcomes of reverse hybrid THA in a consecutive series of patients at medium-term follow-up.

The results of this study are comparable with similar reports. McNally et al[10]] reviewed the results of 100 consecutive reverse hybrid THAs all of whom received an UHMWPE acetabular component, a fully hydroxyapatite (HA) coated stem and a 32 mm ceramic femoral head. The ten-year survival rate (40 hips at risk) for all-cause revision was 94.98% (95% CI 0.87 to 0.98) and 98.95% (95% CI 0.93 to 0.99) for the acetabular and femoral components, respectively. Lan and Lai[[11]] reported on 17 reverse hybrid THAs performed in selected patients with small or severely osteoporotic acetabuli, prior irradiation and sequelae of sepsis in whom cementless acetabular shells were deemed to be unsuitable. At mean follow-up of 40 months, no acetabular components were loose and one stem had subsided. Most recently, Wangen et al[[12]] reported 96.9% implant survival at ten years in a series of 132 reverse hybrid THAs performed in patients under 65 years. All patients received an UHMWPE acetabular component, a fully HA coated stem and a 28 mm ceramic femoral head. They identified one acetabular revision and three stems which had failed due to inadequate proximal osseointegration. Whilst the encouraging results of these studies are comparable with ours, their conclusions are limited by their sample size,[[11]] length of follow-up[[11]] and restricted choice of bearing surface.[[10,12]] The 14th NJR report of 22 552 reverse hybrid THAs reveals a ten-year cumulative percentage probability of revision of 4% (95% CI 3.36 to 4.76)[[1]] which is similar to our results. The most common stem-acetabular-component combination is Corail/Marathon (Depuy Synthes) and whilst ten-year results are awaited, the seven-year cumulative percentage probability of revision is 1.47 (95% CI 1.15 to 1.88) with this combination.[[1]]

In contrast with others,[[21,22]] our study has shown 100% survival of cemented acetabular components for aseptic failure. Our experience indicates that as part of reverse hybrid THA, excellent results at medium-term follow-up can be achieved. RLLs at the bone-cement interface were seen in 7.6% of acetabula in this series but none were progressive in the absence of infection. This compares favourably with other studies where RLLs have been in seen in 36% to 56% of cases.[[10,12]] We found no association between the presence of RLLs and type of polyethylene or femoral head size. Unlike others,[[15,23]] we have not yet found an association between the development of RLLs and progression to failure but our follow-up was short in the context of aseptic loosening and this may change in longer-term follow-up. Contributing factors to the success of cemented acetabular components in this series are likely to include high volume surgery, appropriate training, advances in polyethylene manufacturing, changes in acetabular component design and the use of modern cementing techniques. Cementless acetabular components are currently used in 62.5% of all THAs documented within the NJR[[1]] yet there is little evidence that they are superior to cemented acetabular components in the long-term, despite their increased cost.[[24,25]]

There were no late aseptic stem failures which is consistent with the long-term published data on modern fully HA coated stems.[[26,27]] In each early stem failure, an undersized implant was used which may have led to a failure of osseointegration. The association between smaller Corail stems (size ten or less) and aseptic loosening has previously been reported.[[28]] This error is likely to be attributable to a learning curve[[29]] and highlights the importance of preoperative templating and careful intraoperative assessment of axial and rotational stability. RLLs were most commonly seen in proximal stem zones and the majority of these were clinically silent. We found an association between aseptic stem loosening and younger patients. Whilst this statistical observation is likely to be spurious due to the small number of failures seen in our series, a relationship between younger age and aseptic failure of the Corail stem has previously been observed.[[29]]

The most common complications seen in this series were dislocation (1.8%) and intraoperative femoral PPF (1%). No dislocations were seen with 32 mm heads and only three out of 20 (15%) dislocations occurred in THAs performed by a trainee. A non-significant trend was observed when comparing dislocation rate with head size and surgeon grade and this is the likely result of an underpowered test due to a relatively small number of dislocations. Registry data support the use of 32 mm heads which increase hip stability and reduce revision for dislocation.[[30]] With crosslinked polyethylene, increasing head size from 28 mm to 32 mm has not been shown to adversely affect wear or osteolysis.[[31]] Although we cannot strongly recommend 32 mm heads based on this study, they can be considered a valid option to reduce dislocation. The increased risk of intraoperative femoral PPF with cementless stems is well documented.[[32]] This is often attributable to poor surgical technique where canal entry point is incorrect or an oversized broach or stem is impacted into the canal. Wangen et al[[9]] reported a higher revision rate for postoperative PPF in patients over 55 years receiving a reverse hybrid THA compared with a fully cemented THA in an interrogation of the Nordic Arthroplasty Register. Whilst our study has a comparatively low rate of revision for postoperative PPF, 11 patients (11 hips) suffered this complication intraoperatively, which may have been avoided with improved surgical technique or a modern cemented stem.

The primary strength of our study is the inclusion of a large consecutive series of patients without any restriction on age, gender, indication, head size or femoral bearing surface. Multiple surgeons performed the operations and along with our broad eligibility criteria, these factors enhance the external validity of our conclusions. This study is subject to limitations related to its relatively short follow-up in the context of modern joint replacement, its retrospective design and the absence of formal indications for reverse hybrid THA over other methods of implant fixation. Also, there were no predefined indications for choice of femoral bearing surface or head size other than surgeon preference. Data reliability was improved by cross-referencing electronic institutional records with NJR data and although this method would have identified patients who may have undergone revision at another hospital, we accept that NJR data recording is suboptimal with an estimated 8.67% of missing data for revision THA.[[1]] It is possible that some of the revisions could be missed especially in earlier years when NJR linkage was less accurate. Finally, a lack of patient-reported outcome measures is another drawback but this data was not consistently collected at that time.

This study confirms that reverse hybrid THA offers successful implant survival at medium term follow-up. In order to achieve high quality results, careful attention must be paid to acetabular cementing technique and stem sizing. We recommend paying close attention to the assessment of implant stability, especially when using cementless stems in younger patients with possible metaphyseal/diaphyseal mismatch. Further research is required to investigate second decade survivorship and to compare reverse hybrid implant fixation with other methods.

Take home message

- Reverse hybrid total hip replacement offers highly successful implant survival at medium term follow-up.
- This method of implant fixation can confidently be used in all patients, irrespective of age, gender, head size and surgeon grade.

References

1. **No authors listed.** National Joint Registry for England, Wales, Northern Ireland and the Isle of Man.14th Annual Report, 2017. http://www.njrcentre.org.uk (date last accessed 22 March 2018).[[bibmisc]]

2. **Maggs JL, Smeatham A, Whitehouse SL, et al.** The Exeter Contemporary flanged cemented acetabular component in primary total hip arthroplasty. Bone Joint J 2016;98-B:307-312.

3. **Takenaga RK, Callaghan JJ, Bedard NA, et al.** Cementless total hip arthroplasty in patients fifty years of age or younger: a minimum ten-year follow-up. J Bone Joint Surg [Am] 2012;94-A:2153-2159.

4. **Wyatt M, Hooper G, Frampton C, Rothwell A.** Survival outcomes of cemented compared to uncemented stems in primary total hip replacement. World J Orthop 2014;5:591–596.

5. **Studers P, Belajevs D, Jurkevics V, Likums P.** Ten to fifteen-year clinical and radiographic follow-up with a third-generation cementless stem in a young patient population. Int Orthop 2016;40:465-471.

6. **Unnanuntana A, Dimitroulias A, Bolognesi MP, et al.** Cementless femoral prostheses cost more to implant than cemented femoral prostheses. Clin Orthop Relat Res 2009;467:1546-51.

7. **Berry DJ.** Epidemiology: hip and knee. Orthop Clin North Am 1999;30:183-90.

8. **Lindalen E, Havelin LI, Nordsletten L, et al.** Is reverse hybrid hip replacement the solution? Acta Orthop 2011;82:639–645.

9. **Wangen H, Havelin LI, Fenstad AM, et al.** Reverse hybrid total hip arthroplasty. Acta Orthop 2017;88:248–254.

10. **McNally SA, Shepperd JA, Mann CV, Walczak JP.** The results at nine to twelve years of the use of a hydroxyapatite-coated femoral stem. J Bone Joint Surg [Br] 2000;82-B:378-382.

11. **Lan SM, Lai KA.** Reverse hybrid total hip arthroplasty in select patients. Formosan J Musculoskelet Disord 2010;1:20-25.

12. **Wangen H, Nordsletten L, Boldt JG, Fenstad AM, Beverland DE.** The Corail stem as a reverse hybrid - survivorship and x-ray analysis at 10 years. Hip Int 2017;27:354-360.

13. **Dorr LD, Faugere MC, Mackel AM, et al.** Structural and cellular assessment of bone quality of proximal femur. Bone 1993;14:231-242.

14. **DeLee JG, Charnley J.** Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop Relat Res 1976;121:20-32.

15. **Hodgkinson JP, Shelley P, Wroblewski BM.** The correlation between the roentgenographic appearance and operative findings at the bone-cement junction of the socket in Charnley low friction arthroplasties. Clin Orthop Relat Res 1988;228:105-109.

16. **Gruen TA, McNeice GM, Amstutz HC.** "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res 1979;141:17–27.

17. **Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr.** Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Joint Surg [Am] 1973;55-A:1629-1632.

18. **Archbold HA, Mockford B, Molloy D, et al.** The transverse acetabular ligament: an aid to orientation of the acetabular component during primary total hip replacement: a preliminary study of 1000 cases investigating postoperative stability. J Bone Joint Surg [Br] 2006;88-B:883-886.

19. **No authors listed.** CORAIL Hip System: product rationale and surgical technique http://www.corailpinnacle.net/sites/default/files/DSEMJRC061606652%20CORAIL%20Platform%20Brochure.pdf (date last accessed 5 June 20178).[[bibmisc]]

20. **Campbell D, Mercer G, Nilsson KG, et al.** Early migration characteristics of a hydroxyapatite-coated femoral stem: an RSA study. Int Orthop 2011;35:483–488.

21. **Bordini B, Stea S, De Clerico M, et al.** Factors affecting aseptic loosening of 4750 total hip arthroplasties: multivariate survival analysis. BMC Musculoskelet Disord 2007;8:69.

22. **Berry DJ, Harmsen WS, Cabanela ME, Morrey BF.** Twenty-five-year survivorship of two thousand consecutive primary Charnley total hip replacements: factors affecting survivorship of acetabular and femoral components. J Bone Joint Surg [Am] 2002;84-A:171-177.

23. **Hodgkinson JP, Maskell AP, Paul A, Wroblewski BM.** Flanged acetabular components in cemented Charnley hip arthroplasty. Ten-year follow-up of 350 patients. J Bone Joint Surg [Br] 1993;75-B:464-467.

24. **Abdulkarim A, Ellanti P, Motterlini N, Fahey T, O'Byrne JM.** Cemented versus uncemented fixation in total hip replacement: a systematic review and meta-analysis of randomized controlled trials. Orthop Rev (Pavia) 2013;5:e8.

25. **Pennington M, Grieve R, Sekhon JS, et al.** Cemented, cementless, and hybrid prostheses for total hip replacement: cost effectiveness analysis. BMJ 2013;346:f1026.

26. **Vidalain JP.** Twenty-year results of the cementless Corail stem. Int Orthop 2011;35:189-194.

27. **Sandiford N, Doctor C, Rajaratnam SS, et al.** Primary total hip replacement with a Furlong fully hydroxyapatite-coated titanium alloy femoral component: results at a minimum follow-up of 20 years. Bone Joint J 2013;95-B:467-471.

28. **Jameson SS, Baker PN, Mason J, et al.** Independent predictors of failure up to 7.5 years after 35 386 single-brand cementless total hip replacements: a retrospective cohort study using National Joint Registry data. Bone Joint J 2013;95-B:747-757.

29. **Magill P, Blaney J, Hill JC, Bonnin MP, Beverland DE.** Impact of a learning curve on the survivorship of 4802 cementless total hip arthroplasties. Bone Joint J 2016;98-B:1589-1596.

30. **Huang T, Wang W, George D, Mao X, Graves S.** What can we learn from AOANJRR 2014 annual report? Ann Transl Med 2015;3:131.

31. **Bragdon CR, Doerner M, Martell J, et al.** The 2012 John Charnley Award: clinical multicenter studies of the wear performance of highly crosslinked remelted polyethylene in THA. Clin Orthop Relat Res 2013;471:393-402.

32. **Davidson D, Pike J, Garbuz D, Duncan CP, Masri BA.** Intraoperative periprosthetic fractures during total hip arthroplasty. Evaluation and management. J Bone Joint Surg [Am] 2008;90-A:2000-2012.