Shoulder replacements: a review

Shoulder replacement surgery is a common elective surgical procedure for those with progressive osteoarthritis and rheumatoid arthritis. This review explores the history of shoulder replacements, the different types of replacements and their advantages or disadvantages.

A shoulder replacement is a highly complex and invasive procedure, reserved for patients suffering from degenerative joint diseases where non-surgical options have been exhausted. Some of the most common degenerative joint diseases leading to joint arthroplasty (replacement) are osteoarthritis, rheumatoid arthritis and severe trauma.

According to the National Joint Registry's 12th Annual report in 2015, there were 4756 primary shoulder replacement procedures between 1 April 2014 and 31 December 2014. Of these, 31% involved a replacement of all components of the shoulder joint – a total shoulder replacement (National Joint Registry, 2013). A paper published in the *Journal of Bone and Joint Surgery America* suggested that two thirds of all shoulder replacement surgeries in the USA were performed on adults over 65 years of age. The most common primary diagnosis was osteoarthritis, closely followed by trauma (Kim et al, 2011).

Osteoarthritis and rheumatoid arthritis are far from uncommon; approximately 2% of the population of the UK is affected by rheumatoid arthritis (Alamanos et al, 2006), and 8.7 million people are affected by osteoarthritis (Arthritis Care, 2013). Osteoarthritis, rheumatoid arthritis and trauma have separate indications for surgery, according to pathways published by the National Institute for Health and Care Excellence (2015a,b). It is stated that one should offer patients suffering from rheumatoid arthritis a referral for a surgical opinion if the following symptoms do not respond to pharmacological management: persistent joint pain, worsening joint deformity and function, or continuous synovitis. Patients with osteoarthritis should be given a similar referral for a surgical opinion if they continue to experience pain, stiffness and reduced functions despite exhausting non-surgical management options.

Mr Ahmed Mehmood is 5th year Medical Student, UCL Medical School, University College London, London WC1E 6BT

Mr William Everett is 5th year Medical Student, UCL Medical School, London

Correspondence to: Mr A Mehmood (ahmed.mehmood.11@ucl.ac.uk)

One of the most common traumatic events that may require a joint replacement is a proximal humeral fracture. The management of proximal humeral fractures depends on the type and severity of fracture. Proximal humeral fractures are classified using the Neer classification system (Carofino and Leopold, 2013) which separates the humeral head into four parts, and classifies the type of fracture based on how many parts are formed and which of the parts is displaced:

1. Anatomical head
2. Greater tuberosity
3. Lesser tuberosity
4. Surgical neck.

The classification does not consider the number of fracture lines, but puts emphasis on the number of parts formed because of the fracture and the extent of displacement. Neer separated the types of fractures into one- to four-part fractures (*Figure 1*):

- One-part – anatomical or surgical neck fracture
- Two-part – the fracture line will displace segments two to four
- Three-part – two displaced fragments forming three parts, usually one tuberosity and the surgical neck is displaced while the other tuberosity is not displaced
- Four-part – all segments will be displaced.

The options for management depend on multiple factors – the age of the patient, the type of fracture, health of the bone stock, and danger to surrounding neurovascular structures to name a few (*Table 1*).

The shoulder joint

The shoulder joint is a ball and socket joint consisting of the humeral head and a shallow cup-shaped glenoid fossa (*Figure 2*). Unlike the hip, the shoulder is not a weight-bearing joint, hence the humeral head is not as tightly held in the glenoid fossa as the femur is in the acetabulum. This contributes to both the shoulder joint's greater range of motion and its increased instability. The joint stability relates to the tendons of the rotator cuff muscles. These muscles are:

- Supraspinatus
- Infraspinatus
- Teres minor
- Subscapularis.

Additionally the glenoid fossa is made slightly deeper by a fibrocartilaginous rim (the labrum), adding to the stability afforded by the rotator cuff muscles.

Neurovascularly the humeral head is a particularly active region. The axillary artery surrounded by the nerves from the brachial plexus emerges from underneath the

Figure 1. Diagrammatic illustration of the Neer classification system.

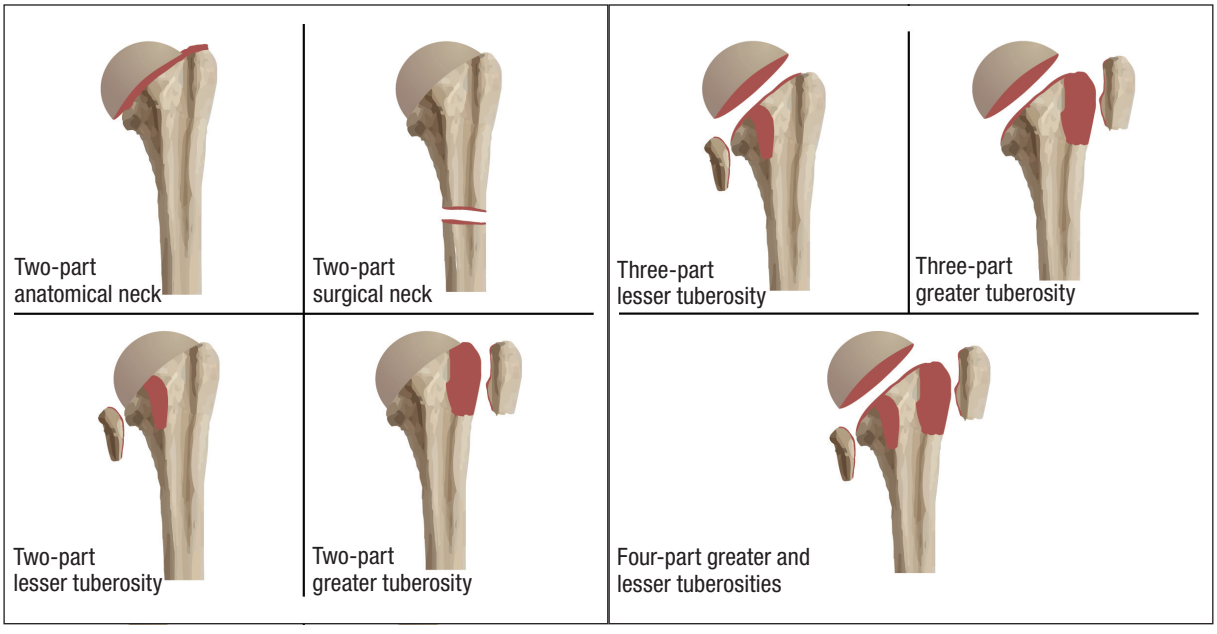


Table 1. Management options for humeral head fractures divided by Neer classification. Replacement is usually reserved for severe trauma that cannot be treated effectively through closed reduction or open reduction internal fixation

Type of fracture	Part	Management	
One-part fracture	Surgical neck	If the fracture is stable aim for early return to movement If the fracture is unstable, normal fracture management applies: reduction if needed, and immobilization	
	Anatomical neck	In younger patients: open reduction with internal fixation In older patients: open reduction with internal fixation or hemiarthroplasty (replacement of humeral head)	
Two-part fracture	Surgical neck	Management can be non-operative, e.g. closed reduction with sling Operative management (mainly open reduction with internal fixation or closed reduction and percutaneous pinning) is indicated for displaced fractures	
	Greater tuberosity	Non-operative management	Indicated by greater tuberosity is undisplaced (or displaced by less than 5 mm)
		Operative management	Indicated if the greater tuberosity is displaced (by more than 5 mm) Isolated screw fixation possible if patient is young
	Lesser tuberosity	Open reduction with internal fixation	
	Anatomical neck	Open reduction with internal fixation or hemiarthroplasty (elderly)	
Three-part fracture	Surgical neck and lesser tuberosity or greater tuberosity		Non-operative: high complications with open reduction with internal fixation treatment
		Young patient	Percutaneous pinning (to help protect axillary nerve function)
		Elderly patient	Replacement
Four-part fracture	Valgus impacted surgical neck or lesser tuberosity		Open reduction with internal fixation or replacement
	Articular and head splitting fracture		Open reduction with internal fixation or replacement

clavicle into the upper arm. The axillary artery gives off two branches that loop around the proximal humerus and humeral head: the posterior and anterior circumflex humeral arteries. These arteries are in very close proximity to potential fractures, increasing the risk of damaging these vessels and eventually leading to ischaemia, poor healing and necrosis. Damage to surrounding nerves can potentially lead to a variety of complications: wrist drop (radial nerve), badge paraesthesia and deltoid wasting (axillary nerve), and ape hand deformity (median nerve) can all occur.

Dr JE Péan and the baker: a brief history of shoulder arthroplasties

It is widely cited that the first total shoulder replacement was undertaken in 1893, by the pioneering French surgeon Jules-Émile Péan. The patient, Mr Jules Perdoux, a 37-year-old baker, was suffering from bony tuberculosis at the time, which was significantly affecting his proximal humerus. The case was further complicated by the formation of an abscess within the muscular compartments surrounding the shoulder, hence Dr Péan's initial thought was to amputate the arm. Mr Perdoux was highly against the idea of amputation, forcing Dr Péan to think of an alternative option, such as replacing the joint with a prosthesis (Bankes and Emery, 1995).

The 1890s was a groundbreaking time for joint arthroplasties – 2 years before Dr Péan's shoulder arthroplasty, Professor T Gluck performed what is believed to be one of the first implantations of a hip prosthesis, which was made of ivory and nickel (Gomez and Morcuende, 2005; Petscavage et al, 2012). Professor Gluck also designed multiple shoulder prostheses made from ivory. However, Dr Péan rejected these prostheses over concerns about their strength. The prosthesis that was eventually used on Mr Perdoux was divided into a shaft and a ball. The shaft was made of platinum and contained multiple holes to allow it to be anchored to the periosteum of the bone using screws. The 'ball' of the prosthesis was analogous to the humeral head, and was constructed from hardened solid rubber (Bankes and Emery, 1995). The procedure was completed in two separate surgeries; the first surgery excised the infected tissues of the shoulder and resected away the humeral head, and the second surgery completed the implantation of the prosthesis (*Figure 3*).

Initially postoperative results were promising; the patient was apyrexial and returned home within 3 weeks. He returned to normal eating, gaining up to 16 kg in the following 2–3 months, and regained a near full range of movement. However, in the ensuing year the patient

Figure 2. The shoulder joint is a very mobile joint allowing for a wide range of movements from abduction, adduction, flexion, extension and circumduction. Its skeletal components consist of a humeral head that fits into a cup-like glenoid fossa.

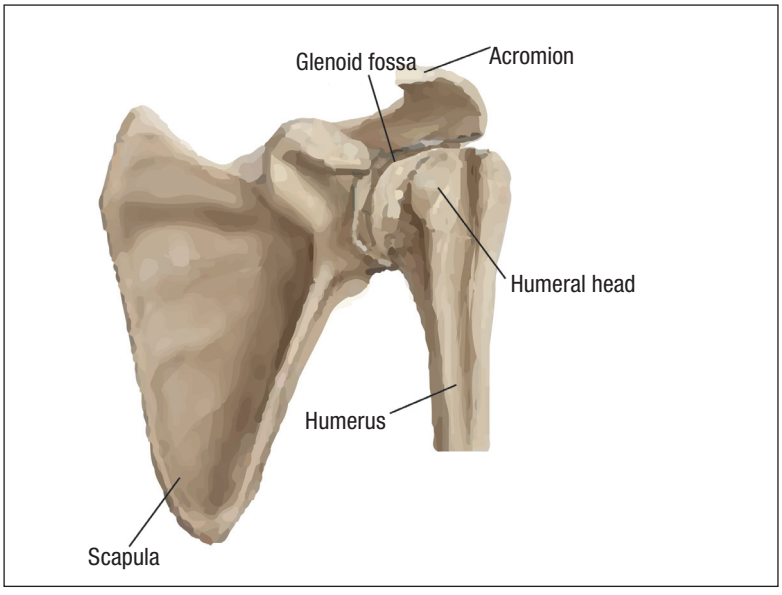


Figure 3. A mock up of what Dr JE Péan's original prosthesis would have looked like. This has been on display in the Smithsonian Museum and the National Museum of Health and Medicine Washington DC.

Figure 4. Diagrammatic illustration of a modern total shoulder replacement.

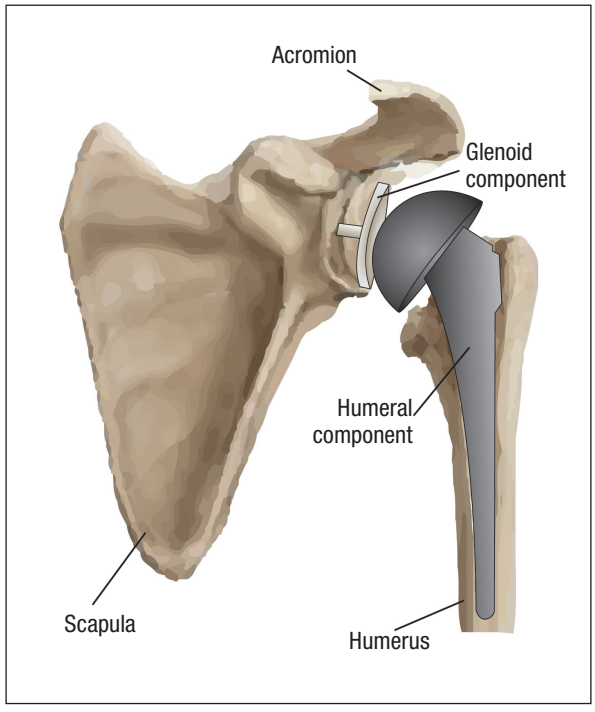
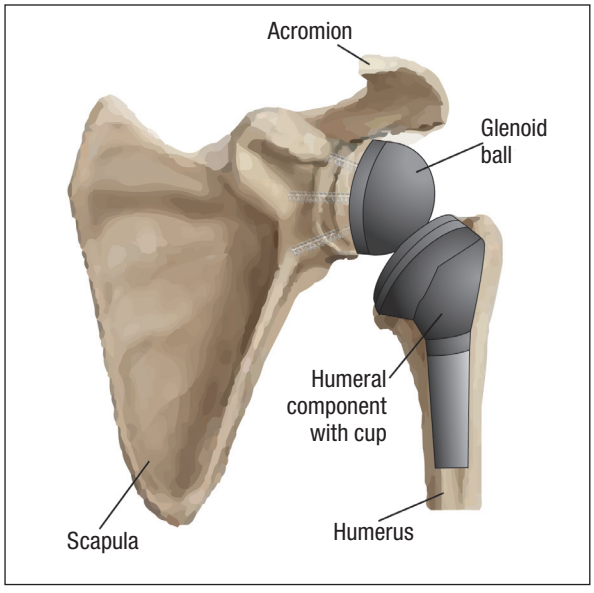


Figure 5. Diagrammatic Illustration of a reverse shoulder replacement. Lengthening the distance from the acromion to the insertion of the deltoid muscle on the humerus reduces the momentary force required for abduction. Additionally, the centre of gravity is closer to the middle of the body reducing any torque around the glenoid component.



suffered from a recurrent abscess and 2 years post surgery a sinus formed on the scar. Dr Péan was forced to operate for a third time to remove the prosthesis, noting that a significant bony shell had formed around it.

Although a lot has changed since Dr Péan's surgery the principles of joint replacement remain the same. In the 1950s, CS Neer described the use of a cobalt, chromium and molybdenum alloy ('Vitallium') prosthesis for proximal humeral arthroplasties to treat osteoarthritic degeneration of the shoulder joint. In his study, he followed 47 patients after their hemiarthroplasty (average follow up time 6 years). He found that the majority of patients (42) were enthusiastic about or satisfied with their results while four remained dissatisfied. Although the small sample size does not lend itself favourably to statistical analysis, it illustrates the growing interest in shoulder replacements (Neer, 1974).

The modern shoulder replacement

The basic concept of the different types of shoulder arthroplasty procedure is to replace either one or both of the constituents of the shoulder joint: the humeral head and the glenoid fossa. There are three main types of shoulder replacements: total shoulder arthroplasties, hemiarthroplasty and reverse shoulder arthroplasties (*Figures 4* and *5*).

Total shoulder replacements or hemiarthroplasty?

Total shoulder arthroplasties involve the removal of the humeral head and a resurfacing of the glenoid fossa, such that both components of the shoulder joint have been replaced with prostheses. Usually the humeral component is made of a metal alloy while the glenoid is resurfaced with a polythene component. A hemiarthroplasty involves replacement of the humeral head without resurfacing the glenoid fossa. The humeral component may be stemmed (cemented or un-cemented), reaching far down into the humeral shaft, or non-stemmed simply acting as a cap. A successful total shoulder arthroplasty procedure is dependent on several factors: the extent of soft tissue function, rotator cuff status and glenoid bone stock. If any of these are lacking it may compromise the procedure.

There have been multiple prospective studies comparing the effectiveness of total shoulder arthroplasty and hemiarthroplasty procedures in patients suffering from osteoarthritis (Wand et al, 2012; Vachtsevanos et al, 2014; Neviaser et al, 2015). Effectiveness is measured as degree of function, pain, range of motion and patient satisfaction. The majority of studies have pointed towards total shoulder arthroplasty being the superior procedure in the mid to short term in terms of pain relief, range of motion, function and patient satisfaction. Despite the short- to mid-term benefit of total shoulder arthroplasties, hemiarthroplasties may be better in the long term as increasing glenoid component damage is seen over time with total shoulder arthroplasties (Clayton et al, 1982; Boyd et al, 1990; Boileau et al, 2006). A large meta-analysis conducted in 2007 investigated the effectiveness of total shoulder arthroplasty and hemiarthroplasties in treating glenohumeral osteoarthritis. This looked at 1952 patients spanning 23 different studies, with a mean follow up of around 3.5 years. The study found that total shoulder arthroplasty significantly improved pain and

range of motion, had greater patient satisfaction, and was less likely to require a secondary surgery (Radnay et al, 2007).

However, work by Copeland suggests that cementless surface replacement arthroplasties can be comparable in outcomes to total shoulder arthroplasties. The Copeland cementless surface replacement arthroplasty was designed specifically for use in arthritic shoulders. The replacement differs from a traditional total shoulder arthroplasty as it only replaces the damaged areas of joint surfaces and allows restoration of joint anatomy with minimal resection. The prosthesis itself consists of a surface replacement cup and short central peg (Levy and Copeland, 2004; Levy et al, 2004).

In a study comparing cementless surface replacement arthroplasty *vs* total shoulder arthroplasties in multiple patients suffering from rheumatoid arthritis and osteoarthritis, between 1986 and 1998, seventy-five rheumatoid shoulders were operated on (33 cementless surface replacement arthroplasty *vs* 42 total shoulder arthroplasty) (Levy et al, 2004). The mean follow up was 6.5 years, and patients were assessed using patient satisfaction, radiographs and constant score (assessment of pain, range of motion and activity). The average Constant score (age- and sex-adjusted) was 71% in the cementless surface replacement arthroplasty group and 76% in the total shoulder arthroplasty group. The mean range of flexion improved from 50° and 47° to 101° and 104° (cementless surface replacement arthroplasty and total shoulder arthroplasty respectively).

Over the same period of time, 79 shoulder replacements (42 total shoulder arthroplasty, 37 cementless surface replacement arthroplasty) were performed for osteoarthritis. Patients were followed up in a similar manner, assessed by self-reported satisfaction, Constant score and radiology. The Constant scores increased from 22.8% to 94% for total shoulder arthroplasty, and 20% to 91% for cementless surface replacement arthroplasty. Active elevation was increased from 59.9° to 128° for total shoulder arthroplasty, and 124° for cementless surface replacement arthroplasties. Although the results for both total shoulder arthroplasty and cementless surface replacement arthroplasty in both rheumatoid arthritis and osteoarthritis were comparable, shoulder resurfacing has several advantages including bone preservation, and avoiding complications of using stemmed prostheses in diseased bone. As bone stock can be maintained, if revisions or conversion to total shoulder arthroplasty are required, they can be undertaken with relative ease (Levy and Copeland, 2004).

In many areas of orthopaedic surgery there is a push towards the use of smaller incisions and prostheses to allow preservation of the normal anatomy. Previously described bone-sparing technology such as the hemiarthroplasty and partial replacements of the head do not fully allow glenoid replacement. There are also situations where a full-stemmed conventional implant is not favourable, e.g. patients with humeral disfigurement or previous elbow replacement are not anatomically suitable for traditional full-stemmed replacements. The use of ministem technology can have advantages of reducing reaming during insertion. The resulting reduction in stress can lead to a reduced risk of fractures. The decreased loss of bone stock can provide the potential benefit of easier stem removal, reduced need for osteotomy and hence easier revision surgeries. Further investigations are necessary to evaluate the long-term efficacy of these prostheses and to assess the potential advantages (Jost et al, 2011).

The National Joint Registry's (2013) data showed that the vast majority of surgical approaches for both hemiarthroplasties and total shoulder arthroplasties were the deltopectoral approach. This involves making a 15 cm skin incision between the bony landmark of the coracoid process and the proximal humeral shaft. The deltopectoral groove is blunt dissected to expose the clavipectoral fascia. Once the fascia has been opened, the shoulder joint can be visualized and the procedure can be carried out.

Reverse shoulder replacements

From the 1950s to the 1980s, Neer was publishing his findings for hemiarthroplasties in patients with osteoarthritis. In the early 1980s he began to acknowledge that the performance of total shoulder arthroplasties and hemiarthroplasty, in terms of function and range of movement, rapidly declined with advancing implant age especially in patients with preexisting rotator cuff injuries. Reverse shoulder replacements were designed to overcome this limitation. Since Neer's initial findings, multiple studies have looked into the limited functional results of total shoulder arthroplasties and hemiarthroplasties when used in patients with both glenohumeral osteoarthritis and rotator cuff injuries. These patients were said to present with a 'painful pseudo-paralytic' shoulder (Boileau et al, 2006).

A reverse shoulder replacement is similar to a total shoulder replacement in that both the glenoid and the humeral head are replaced. However, in this case the action of the humeral head and the glenoid fossa are 'reversed'. The humeral head is replaced with a cup-like socket prosthesis while the glenoid is replaced with a ball component acting analogous to a new humeral head. The reverse shoulder replacement acts to combat the complications that would normally occur with a total shoulder arthroplasty. It allows the patient to abduct the arm at the shoulder by using less force and it reduces the shear force on the glenoid component, lessening the chance of glenoid loosening and the need for a second surgery.

This is done by medializing the centre of gravity in the shoulder joint; the prosthesis acts to reduce shear forces around the glenoid component. Now that the new centre of gravity is closer to the centre of the body and the humerus is slightly lengthened, the deltoid has a longer fulcrum to act upon, and so less force is needed to generate

the normal moment (aka torque) to lift (abduct) the arm. This has a tremendous effect in patients with a rotator cuff tear, as it allows the deltoid muscle to act to overcome any rotator cuff weakness.

Reverse shoulder arthroplasties had been thought to have greater complication and revision rates, however, work published by Gee et al (2015), looking at a total of 121 rheumatoid shoulders that underwent reverse shoulder arthroplasties, suggested that these concerns were not valid, as 95% described excellent to satisfactory outcomes (Gee et al, 2015). Reverse shoulder arthroplasties could provide predictable improvements in multiple key outcome measures (Wiater and Fabing, 2009; Smith et al, 2012).

Conclusions

There are several different types of shoulder replacements, each with their own unique indications for use and associated caveats. Long-term studies suggest that total shoulder arthroplasties show improvements over hemiarthroplasties and reverse shoulder arthroplasties in relief of pain, range of motion, functionality and patient satisfaction. Additionally, works published by Copeland and others suggest that hemiarthroplasty and total shoulder arthroplasties are relatively comparable in outcome but joint resurfacing has the added benefits of reduced complication and maintained bone stock.

Papers have been published on the use of reverse shoulder arthroplasties electively, in patients suffering from chronic conditions. The outcome of anatomical shoulder replacements is dependant on an intact rotator cuff, but in patients with rheumatoid arthritis these shoulder replacements can become complicated by a high incidence of rotator cuff tear and glenoid wear. **BJHM**

Conflict of interest: none.

KEY POINTS

- A shoulder replacement is a procedure reserved for patients suffering from degenerative joint diseases where non-surgical options have been exhausted.
- The first total shoulder replacement was undertaken in 1893 by Jules-Émile Péan.
- The basic concept of shoulder arthroplasty procedures is to replace either one or both of the constituents of the shoulder joint: the humeral head and the glenoid fossa.
- There are three main types of shoulder replacements: total shoulder arthroplasties, hemiarthroplasty and reverse shoulder arthroplasties.
- Previous works suggest that hemiarthroplasty or Copeland surface replacement arthroplasty and total shoulder arthroplasties are relatively comparable in outcome but Copeland surface replacement arthroplasty has the added benefits of reduced complication and maintained bone stock.
- A reverse shoulder replacement acts to combat complications that would otherwise occur with a conventional total shoulder arthroplasty. It allows the patient to abduct the arm at the shoulder with reduced force, and it reduces the shear force on the glenoid component, lessening the chance of glenoid loosening and the need for a second surgery.

Alamanos Y, Voulgari PV, Drosos AA (2006) Incidence and prevalence of rheumatoid arthritis, based on the 1987 American College of Rheumatology criteria: a systematic review. *Semin Arthritis Rheum* **36**: 182–8 (doi: 10.1016/j.semarthrit.2006.08.006)

Arthritis Care (2013) Osteoarthritis In General Practice. Data and perspectives. www.arthritisresearchuk.org/policy-and-public-affairs/reports-and-resources/~/media/1C04D81E4C6048048E0246F588A0CD64.ashx (accessed 16 January 2016)

Bankes MJ, Emery RJ (1995) Pioneers of shoulder replacement: Themistocles Gluck and Jules Emile Péan. *J Shoulder Elbow Surg* **4**(4): 259–62

Boileau P, Sinnerton RJ, Chuinard C, Walch G (2006) Arthroplasty of the shoulder. *J Bone Joint Surg Br* **88**(5): 562–75 (doi:10.1302/0301-620X.88B5)

Boyd AD, Jr, Thomas WH, Scott RD, Sledge CB, Thornhill TS (1990) Total shoulder arthroplasty versus hemiarthroplasty. Indications for glenoid resurfacing. *J Arthroplasty* **5**: 329–36

Carofino BC, Leopold SS (2013) Classifications in Brief: The Neer Classification for Proximal Humerus Fractures. *Clin Orthop Relat Res* **471**(1): 39–43 (doi: 10.1007/s11999-012-2454-9)

Clayton ML, Ferlic DC, Jeffers PD (1982) Prosthetic arthroplasties of the shoulder. *Clin Orthop Relat Res* ?? 184–91

Gee ECA, Hanson EK, Saithna A (2015) Reverse shoulder arthroplasty in rheumatoid arthritis: a systematic review. *Open Orthop J* **9**: 237–45 (doi: 10.2174/1874325001509010237)

Gomez PF, Morcuende JA (2005) Early attempts at hip arthroplasty—1700s to 1950s. *Iowa Orthop J* **25**: 25–9

Jost PW, Dines JS, Griffith MH, Angel M, Altcheck DW, Dines DM (2011) Total shoulder arthroplasty utilizing mini-stem humeral components: technique and short-term results. *HSS J* **7**(3): 213–17 (doi: 10.1007/s11420-011-9221-4)

Kim SH, Wise BL, Zhang Y, Szabo RM (2011) Increasing incidence of shoulder arthroplasty in the United States. *J Bone Joint Surg Am* **93**: 2249–54 (doi: 10.2106/JBJS.J.01994)

Levy O, Copeland SA (2004) Cementless surface replacement arthroplasty (Copeland CSRA) for osteoarthritis of the shoulder. *J Shoulder Elbow Surg* **13**(3): 266–71 (doi:10.1016/j.jse.2004.01.005)

Levy O, Funk L, Sforza G, Copeland SA (2004) Copeland surface replacement arthroplasty of the shoulder in rheumatoid arthritis. *J Bone Joint Surg Am* **86A**(3): 512–18

National Institute for Health and Care Excellence (2015a) Management of osteoarthritis. http://pathways.nice.org.uk/pathways/osteoarthritis (accessed 16 January 2016)

National Institute for Health and Care Excellence (2015b) Managing rheumatoid arthritis. http://pathways.nice.org.uk/pathways/rheumatoid-arthritis (accessed 16 January 2016)

National Joint Registry (2015) 12th annual report 2015. www.njrcentre.org.uk/njrcentre/Reports,PublicationsandMinutes/Annualreports/tabid/86/Default.aspx (accessed 16 January 2016)

Neer CS (1974) Replacement arthroplasty for glenohumeral osteoarthritis. *J Bone Joint Surg Am* **56**(1): 1–13

Neviaser RJ, Resch H, Neviaser AS, Crosby LA (2015) Proximal humeral fractures: pin, plate, or replace. *Instr Course Lect* **64**: 203–14

Petscavage JM, Ha AS, Chew FS (2012) Current concepts of shoulder arthroplasty for radiologists: Part 1--Epidemiology, history, preoperative imaging, and hemiarthroplasty. *AJR Am J Roentgenol* **199**: 757–67

Radnay CS, Setter KJ, Chambers L, Levine WN, Bigliani LU, Ahmad CS (2007) Total shoulder replacement compared with humeral head replacement for the treatment of primary glenohumeral osteoarthritis: a systematic review. *J Shoulder Elbow Surg* **16**: 396–402

Smith CD, Guyver P, Bunker TD (2012) Indications for reverse shoulder replacement: a systematic review. *J Bone Joint Surg Br* **94**(5): 577–83

Vachtsevanos L, Hayden L, Desai AS, Dramis A (2014), Management of proximal humerus fractures in adults. *World J Orthop* **5**(5): 685–93 (doi: 10.5312/wjo.v5.i5.685)

Wand RJ, Dear KE, Bigsby E, Wand JS (2012) A review of shoulder replacement surgery. *J Perioper Pract* **22**(11): 354–9

Wiater JM, Fabing MH (2009) Shoulder arthroplasty: prosthetic options and indications. *J Am Acad Orthop Surg* **17**(7): 415–25