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REVIEW

The Evolution of Reverse Shoulder Arthroplasty: A Review of Complications and the Rising Concern of Overuse

Praveen Baskaran[1,*], Maxwell S. Renna[1], Ashley I. Simpson[2]

[1]Department of Trauma and Orthopaedics, Guy's and St Thomas' NHS Foundation Trust, London, UK
[2]Peripheral Nerve Injury Unit, The Royal National Orthopaedic Hospital NHS Trust, London, UK
*Correspondence: Praveen.baskaran@nhs.net (Praveen Baskaran)

Abstract

Reverse shoulder arthroplasty (RSA) was initially developed to manage cuff tear arthropathy in elderly patients. It has since become increasingly popular due to its ability to provide pain relief, enhance stability, and improve function in various complex shoulder pathologies. This review examines the evolution of RSA, including its expanded indications for use, complications, and the rising concern of potential overuse. While RSA has shown significant benefits in selected cases, its growing application in younger and more active patients raises questions about long-term outcomes and durability. Complications such as instability, infection, baseplate failure, and scapular notching remain substantial challenges, particularly in revision cases. The article emphasises the need for cautious patient selection and evidence-based practice to avoid overuse and ensure optimal patient outcomes. Future high-quality research with extended follow-up is essential to better understand RSA's long-term efficacy and safety, particularly in diverse and younger patient populations.

Key words: reverse shoulder arthroplasty; usage trends; complication; management; overuse

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Introduction

Reverse shoulder arthroplasty (RSA) was developed for managing cuff tear arthropathy in elderly patients. It involves reversing the anatomical configuration of the shoulder, transforming the biomechanics and allowing the deltoid to compensate for the impaired rotator cuff. RSA has demonstrated considerable results in providing pain relief, enhancing stability, and improving function (Boileau, 2016; Cvetanovich et al, 2019; Rugg et al, 2019).

Over the past two decades, there has been a marked increase in the utilisation of RSA. In the UK, procedures have increased from around 1500 in 2005 to approximately 9000 in recent years (National Joint Registry, 2024) . This trend is similarly observed in the United States, as demonstrated by Rabinowitz et al (2020) using data from the National Inpatient Sample (NIS). Their retrospective analysis revealed a 1373% growth in RSA procedures from 1997 to 2016, with the number of cases increasing from 6653 to 97,995. The study also projected that total shoulder arthroplasty cases will surpass 200,000 annually by 2040. This growth may be attributed to broader indications, advancements in implant designs, and an ageing

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population (Best et al, 2021; Valsamis et al, 2023). A meta-analysis by Rupani et al (2024) further supports this trend, showing a significant rise in RSA procedures across countries such as Germany, the Netherlands, Sweden and Norway.

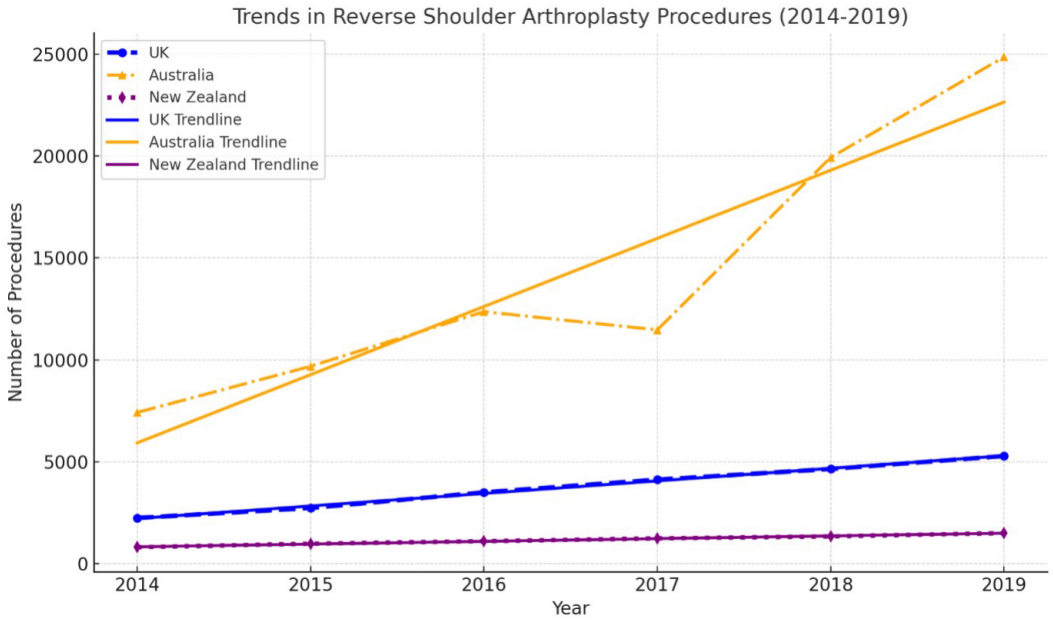

Fig. 1. Trends in reverse shoulder arthroplasty (RSA) procedures in the UK, Australia, and New Zealand from 2014 to 2019. The figure was created by the authors using Microsoft Excel (Version 16.0, Microsoft Corporation, Redmond, WA, USA), and the statistical analysis was performed using Python's SciPy library (Version 1.10.1, Python Software Foundation, Wilmington, DE, USA).

In Fig. 1 the y-axis represents the total number of RSA procedures performed annually. Linear regression analysis revealed statistically significant increases in RSA utilisation across all three countries. The annual increase was steepest in Australia ($R^2 = 0.875$, $p = 0.006$), followed by the UK ($R^2 = 0.997$, $p < 0.001$) and New Zealand ($R^2 = 0.995$, $p < 0.001$). UK data was sourced from the National Joint Registry (2024), Australian data from the Australian Orthopaedic Association National Joint Replacement Registry (2024), and New Zealand data from the New Zealand Orthopaedic Association (2024).

Current studies on RSA's long-term outcomes are predominantly based on retrospective case series and cohort studies, which lack randomisation and control groups, leading to potential biases. These studies often do not capture the full scope of complications, particularly in younger, more active patients, making it difficult to assess implant longevity and the risks of revision.

Indications have expanded to include irreparable rotator cuff tears without advanced arthropathy, complex proximal humerus fractures, severe glenoid bone loss or deformity, revision arthroplasty, and following tumour resection (Best et al, 2021).

Long-term data on RSA efficacy, survivability and complications remain sparse. The UK's National Institute for Health and Care Excellence (2020) (NICE) has em-

phasised the need for caution, highlighting the lack of robust evidence supporting the expanding range of indications. Current literature predominantly consists of case series and studies addressing specific complications and their treatment options.

The Proximal Fracture of the Humerus: Evaluation by Randomisation II (PROFHER II) Randomised Controlled Trial (RCT) represents a significant advancement, addressing a critical need for randomised data on RSA's effectiveness in displaced proximal humeral fractures in older adults—an area where RSA is widely used yet minimally supported by high-level evidence (Rangan et al, 2023). By comparing RSA with non-surgical management, PROFHER II aims to deliver robust data on key clinical outcomes, including pain relief, functional gains, complication rates, and cost-effectiveness. Its findings are anticipated to guide practice by clarifying RSA's role in managing complex fractures, a prevalent but challenging indication in elderly patients.

This article aims to synthesise current literature, providing an overview of the history of RSA, principles behind the technique, common complications, management options and suggested patient selection. It will also explore the frequency of RSA use and consider the potential for overuse.

History of RSA

The history of shoulder arthroplasty dates to the 1800s, when it was first implemented in clinical practice (Flatow and Harrison, 2011). In 1893, Jules Emile Pean conducted the first total shoulder arthroplasty (TSA) on a patient with tuberculosis (Bankes and Emery, 1995). This procedure involved the implantation of platinum and rubber components, which initially improved strength and range of motion (ROM) but ultimately failed, necessitating removal within two years.

Significant progress occurred in the 1950s when Charles Neer began implanting Vitallium prostheses for trauma (Neer, 1955). By 1974, Neer (1974) reported satisfactory outcomes in patients undergoing TSA. However, despite achieving pain relief, many cases in the late 1970s exhibited superior head migration, a complication undermining their long-term success.

A major breakthrough emerged when Grammont and Baulot (1993) identified the limitations of TSAs in patients with absent or damaged rotator cuffs, as illustrated in Fig. 2. Grammont et al (1985) proposed a radical approach by reversing the conventional shoulder joint anatomy, positioning a convex humeral component and a concave glenoid component. This innovative design shifted the centre of rotation (COR) of the shoulder medially and inferiorly, allowing the deltoid muscle to compensate for the deficient rotator cuff. This approach restored ROM and stability in patients previously failed by traditional TSAs (Grammont et al, 1985; Willems, 2021). By 1985, Grammont et al (1985) had developed the first generation of the Grammont prosthesis, known as the Delta prosthesis.

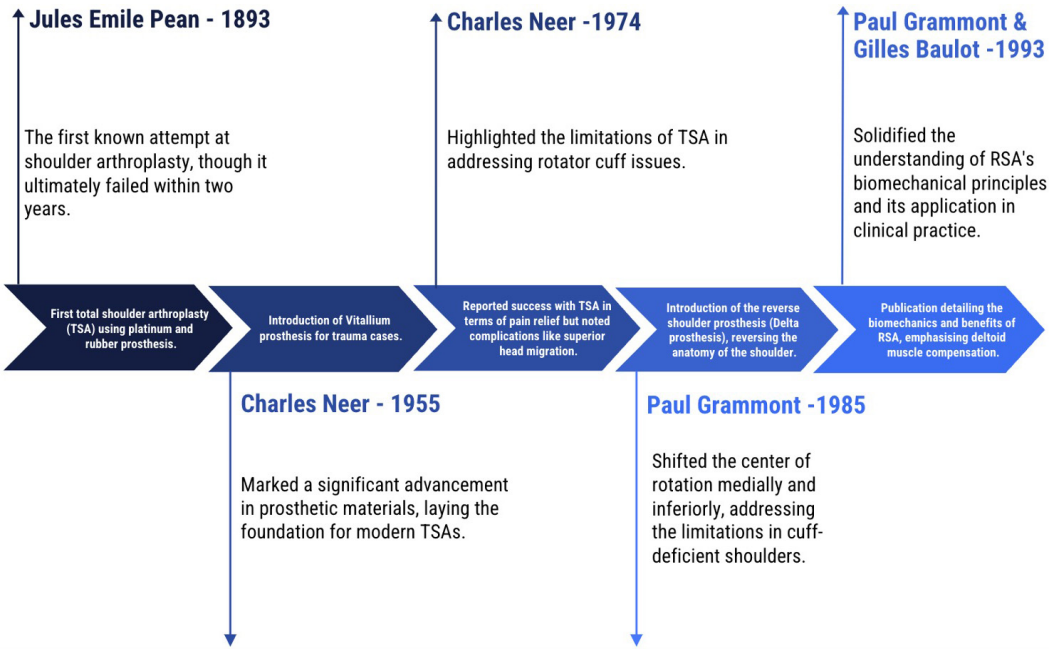

Fig. 2. Key milestones in the development of reverse shoulder arthroplasty (RSA). The timeline shows major contributions to the development of RSA, from Jules Emile Pean's first shoulder arthroplasty in 1893 to Paul Grammont's revolutionary Delta prosthesis in 1985. Significant events include the introduction of Vitallium prostheses by Charles Neer and the publication of biomechanical advancements by Paul Grammont and Gilles Baulot. This figure was created by the authors using the online platform Venngage (Version 2024, Venngage Inc., Toronto, Canada). The historical data was sourced from Grammont and Baulot (1993), Neer (1955), Neer (1974), Grammont et al (1985) and Bankes and Emery (1995). TSA, total shoulder arthroplasty.

Principles of RSA

The Grammont et al (1985) design introduced critical biomechanical features that enhanced joint functionality and stability. One key aspect is medialisation of the COR, which extends the deltoid's lever arm, increasing the torque produced by the deltoid (Frank et al, 2022). This medialisation converts torque forces into compressive forces across the bone-glenosphere interface, providing joint stability in the absence of the rotator cuff (Boileau, 2016; Rugg et al, 2019), as seen in Fig. 3.

Moreover, the design distalises the humerus, re-tensioning the deltoid, further improving its effectiveness in generating movement. The RSA implant features a constant COR, resulting in an inherently stable prosthesis and reducing the risk of dislocation. This semi-constrained prosthesis also creates a wider ROM, allowing for improved function (Grammont et al, 1985) and thereby significantly enhancing patient outcomes.

Complications and Management

The incidence rates for complications in RSA show considerable variability across studies. This variability arises from methodological differences, such as the inclusion of primary versus revision cases, which have distinct risk profiles, as well

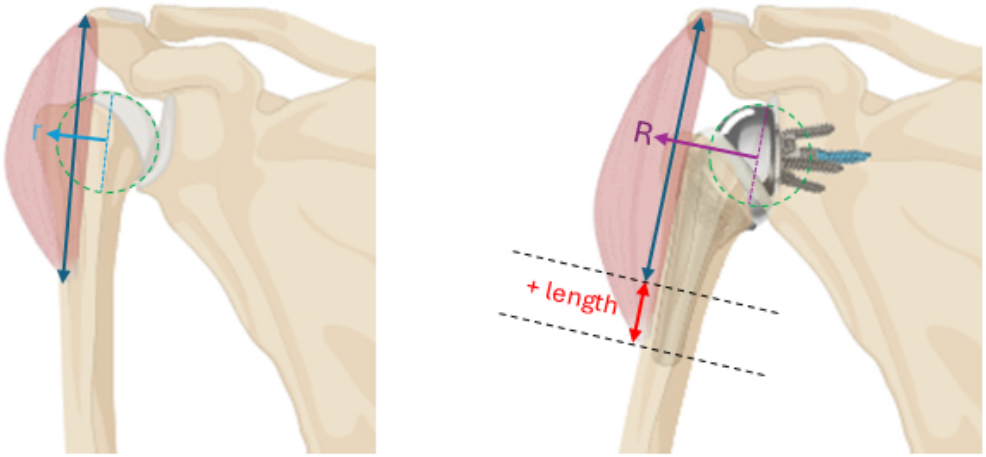

Fig. 3. Biomechanics of reverse shoulder arthroplasty (RSA). The left illustration depicts the natural shoulder anatomy, with the humeral head centred in the glenoid. The right shows post-RSA biomechanics, where the humeral head is replaced by a prosthetic glenosphere and the glenoid by a baseplate. This results in medialisation and distalisation of the centre of rotation (R, purple arrow; r, light blue arrow), as well as lengthening of the deltoid moment arm (dark blue arrows), enhancing deltoid muscle tension and mechanical advantage. The red arrow represents the increased deltoid length post-RSA. Figure created by authors using BioRender software (Version 5.5, BioRender, Toronto, ON, Canada) and Canva Visual Suite (Version 3.10, Canva Inc., Sydney, NSW, Australia).

as variations in patient selection, implant designs, and surgical techniques. Table 1 summarises these complications, their incidence, and the management strategies.

Retrospective cohort studies and case series, which make up the majority of RSA research, often introduce selection and reporting biases. For example, single-centre studies may report lower complication rates due to specialist expertise, while registry-based analyses may capture broader but less detailed data (Glanzmann et al, 2020; Olson et al, 2022).

Furthermore, patient-specific factors—including age, activity level, and co-morbidities may significantly influence complication rates, particularly in infection and instability outcomes (Contreras et al, 2020; Shah et al, 2021). Recent evidence also indicates that morbid obesity and liver disease may increase the likelihood of complications, especially periprosthetic dislocation, underscoring the need for careful patient selection in RSA (Otworowski et al, 2023).

This variability highlights the need for standardisation in RSA outcome reporting to enable more accurate comparisons and improve clinical decision-making. Future research should prioritise multicentre, prospective studies with clearly defined patient populations and outcome measures to better assess complication risks. Such studies would provide clinicians with reliable data to refine patient selection criteria and tailor management strategies, ultimately reducing the incidence of complications and revision surgeries.

Table 1. Summary of complications, incidence, and management in reverse shoulder arthroplasty (RSA).

Complication	Incidence	Management options
Instability	0.4% to 49% (varies by study) (Olson et al, 2022)	Early dislocation: Closed reduction; Late dislocation: Surgical reintervention including humeral shortening, larger polyethylene components, or glenosphere replacement (Boileau, 2016)
Infection	3% to 4% (range: 0.5% to 6.7%) (Contreras et al, 2020)	Non-surgical: Activity modification, pain management; Surgical: Revision surgery, bone grafting, implant augment, larger screws, custom components (Contreras et al, 2020; Jacquot et al, 2023)
Baseplate failure	0.9% in primary procedures, 3.6% in revision cases (Rojas et al, 2019)	Surgical: Revision surgery, bone grafting, component replacement, larger screws, glenoid augment, optimise component positioning (Rojas et al, 2019)
Scapular notching	4.6% to 50.8% (Castagna et al, 2022)	Optimise implant design, eccentric glenosphere size, and component positioning to mitigate risk of notching (Jang et al, 2020)
Acromion and scapular spine fractures	0.8% to 11.2% (Cassidy et al, 2022)	Non-operative management: Immobilisation and physical therapy; Surgical: Open reduction and internal fixation (ORIF) if displaced (Boltuch et al, 2022)
Neurovascular complications	1% to 4% (Vajapey et al, 2021)	Nerve injuries: Physical therapy, surgical exploration and repair (Zhou et al, 2015); Vascular injuries: Monitoring, anticoagulation, thrombectomy, or vascular repair

Instability

Instability refers to improper movement or dislocation of the artificial joint components. This can manifest as inability of the prosthesis to maintain correct alignment during movement or rest, leading to discomfort and functional limitations. Instability in itself represents a spectrum of symptoms from subjective apprehension, either at rest or during movement, to objective dislocation of the prosthesis, and thus can lead to the reporting of widely varied incidence rates in the literature.

A systematic review conducted by Olson et al (2022), considering 7885 cases of RSA, exposes instability rates ranging from 0.4% to 49%. This variance originates from the combination of data reflecting primary RSA, revisions, and studies combining both, demonstrating instability rates of 1–5%, 1–49%, and 0.4–10%, respectively. A retrospective cohort study by Glanzmann et al (2020) identified a revision rate for instability at 0.5% among 1480 primary RSAs.

Patient factors which are predictive of instability include revision status, male sex, body mass index (BMI) >30, inadequate deltoid tension, and infection (Shah et al, 2021). Abdelfattah et al (2018) introduced a classification comprising three primary causes: loss of compression, loss of containment, and impingement. Loss of compression includes deltoid dysfunction, deltoid under-tensioning, and an irreparable subscapularis. Loss of containment addresses mechanical failure, while

impingement involves soft tissue or bony impingement and prosthetic malalignment.

Management of instability requires an understanding of the underlying cause. Early dislocations, occurring within the first three months post-surgery, are typically addressed with closed reduction under general anaesthesia, although success rates for this approach remain modest (Boileau, 2016). Late dislocations, occurring after three months, often necessitate surgical intervention, with recurrent cases commonly linked to inadequate deltoid tension or medialisation, necessitating careful planning for revision surgery (Boileau, 2016).

In cases where humeral shortening is needed to improve stability, options include the use of larger polyethylene components or complete replacement of the humeral implant (Boileau et al, 2005). Medialisation can be managed with a larger glenosphere or by revising the glenoid implant to enhance compression forces and reduce impingement risk (Boileau, 2016). Humeral shortening techniques, as discussed by Tross et al (2021), may contribute to bone preservation and facilitate revision surgery, particularly with short-stem implants.

In addressing glenoid deficiencies, using a larger glenosphere may help to medialise the centre of rotation, potentially improving compression forces and reducing the risk of impingement (Imiolczyk et al, 2024). In cases of instability or malalignment of the glenoid baseplate, revising with enhanced fixation strategies, such as longer screws or bone graft augmentation, could promote stability. Additionally, augmented glenoid implants or bone grafts may enhance stability through improved anatomical congruity.

A recent retrospective study identified a 20–40% recurrence rate of instability post-revision RSA, primarily attributed to loss of compression, with multiple revisions correlating with reduced stability outcomes (Melbourne et al, 2023).

Boileau (2016) reported that closed reduction for early dislocations achieves a success rate of 30–50%. For late dislocations, revision procedures exhibit variable outcomes depending on the techniques employed, with humeral shortening combined with larger polyethylene components often associated with improved joint stability (Boileau et al, 2005).

Infection

A recent analysis indicates the incidence of periprosthetic joint infection (PJI) is 3% to 4%, although documented rates vary from 0.5% to 6.7% (Contreras et al, 2020). Notably, in a study scrutinising 4063 post-operative complications following shoulder arthroplasty, Somerson et al (2017) found that infections following RSA accounted for 13.8% of all reported RSA-related complications.

Despite representing a significant complication burden, the identification of PJI remains challenging. Often, the only suggestion of PJI is a patient reporting unexplained pain. To address this, the International Consensus Meeting on Orthopaedic Infections in 2018 introduced a classification system for periprosthetic shoulder infections, categorising them into four distinct groups: definite infection, probable infection, possible infection, and unlikely infection (Garrigues et al, 2019). This system employs major and minor criteria that include specific indicators such

as sinus tracts, positive cultures, and inflammatory markers like c-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) (Garrigues et al, 2019). However, the effectiveness of this identification system requires further evaluation, with limited data currently describing its specificity and sensitivity.

The diagnosis of PJI is further complicated by the primary organism implicated in infection—*Cutibacterium acnes*, an anaerobic gram-positive organism of low virulence (Jacquot et al, 2023; Shah et al, 2021). Due to its low virulence, it may be associated with underwhelming blood infection markers and clinical findings. This organism, which exists naturally in the skin, particularly in the axilla, is considered to be more abundant in men, perhaps accounting for the increased prevalence of PJI in male patients (Contreras et al, 2020; Shah et al, 2021).

Other risk factors for PJI include younger age, smoking, elevated BMI, hepatitis C, human immunodeficiency virus (HIV), and Parkinson's disease. Moreover, surgical indications such as proximal humeral fractures and revision surgery both carry greater risks (Shah et al, 2021; Somerson et al, 2017).

The management of PJI involves appropriate microbiology sampling with a targeted course of antibiotic therapy combined with surgical intervention, including debridement and implant retention (DAIR), and/or one-stage or two-stage revision (Contreras et al, 2020; Garrigues et al, 2019). As demonstrated in Fig. 4, antibiotic-loaded cement spacers are employed in two-staged revision surgeries to maintain joint alignment and deliver high concentrations of local antibiotics. A meta-analysis conducted by Aïm et al (2020) indicates that one-stage revision reflects a lower reinfection rate of 7% compared to the 21% rate observed with two-stage revision. Moreover, the analysis highlights that the one-stage revision approach demonstrates lower complication rates at 17%, in contrast to the 33% complication rate associated with two-stage revision (Aïm et al, 2020).

Prophylactic antibiotic use is critical for reducing periprosthetic joint infections (PJIs) in RSA, particularly against *Cutibacterium acnes*, a common pathogen in shoulder surgeries (Longo et al, 2020). Longo et al's (2020) systematic review highlights the challenges of eradicating *Cutibacterium acnes*, emphasizing that single-agent cefazolin is generally effective, though controversies remain regarding optimal prophylactic regimens due to antibiotic resistance concerns.

A large retrospective cohort study by Marigi et al (2022) demonstrated that cefazolin significantly lowers PJI risk compared to alternatives like vancomycin and clindamycin, showing a 78% reduction in *Cutibacterium acnes* infections. This study's strength lies in its multivariable analysis of over 7000 shoulder arthroplasties, providing robust evidence favouring cefazolin. For patients with beta-lactam allergies, alternatives may require additional measures due to their higher associated infection rates.

When managing PJIs in RSA, the timing and approach of revision surgery are critical. Acute infections, typically occurring within three months post-surgery, may be effectively managed with a single-stage revision involving thorough debridement and implant exchange, which has shown promising infection control outcomes (Aïm et al, 2020; Markes et al, 2023). For chronic infections, which develop more than 12 months after surgery, a two-stage revision is generally rec-

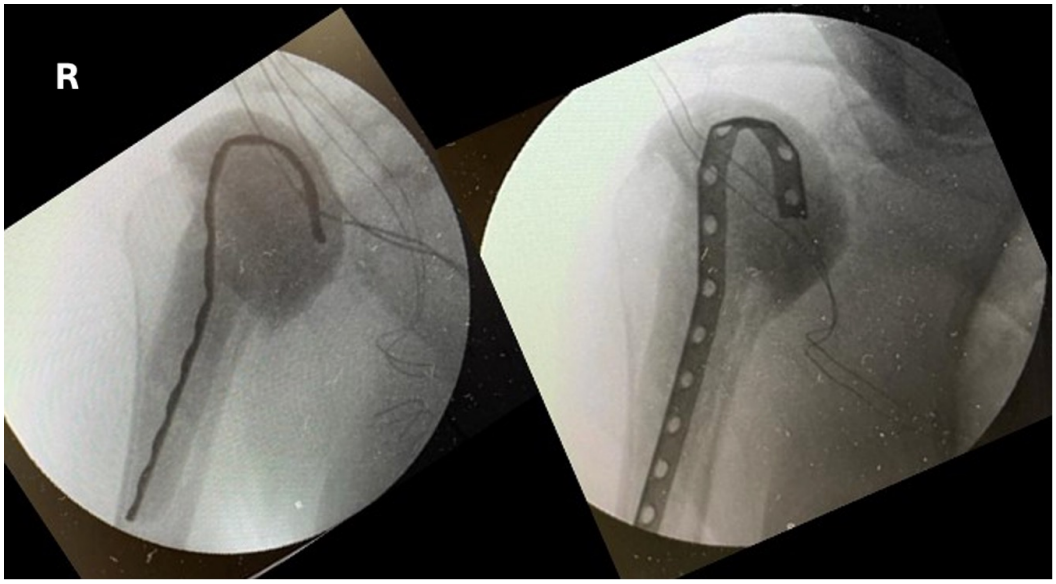

Fig. 4. Intraoperative image intensifier images of an antibiotic-loaded cement spacer moulded around a contoured 12-hole stainless steel 1/3 tubular plate for the management of periprosthetic joint infection around an explanted reverse shoulder arthroplasty. Radiographs were obtained by authors with patient consent. The letter 'R' indicates the right side.

ommended. This involves removing the infected prosthesis, placing an antibiotic spacer, and delaying reimplantation until infection markers normalise. Although two-stage revisions are effective for chronic infections, they may carry a higher complication rate compared to single-stage procedures (Aïm et al, 2020; Markes et al, 2023).

Baseplate Failure

Baseplate failure refers to the malfunction of the baseplate component, crucial for implant stability and function.

Although this complication is relatively rare, a meta-analysis by Rojas et al (2019) indicates an incidence of 0.9% in primary procedures and 3.6% in revision cases, while a 15-year retrospective analysis by John et al (2024) identified a higher incidence of 6.8% in cases requiring revision for baseplate failure among 676 failed RSA procedures. The lowest incidence is observed in RSA performed for proximal humerus fractures, while the highest occurs in cases of osteoarthritis with glenoid bone loss (Rojas et al, 2019). Interestingly, there is no significant difference in failure rates between medialised and lateralised implant systems, highlighting the critical role of bone quality in baseplate stability (Rojas et al, 2019)

As seen in Fig. 5, X-ray findings can reveal displacement of the baseplate and glenosphere in RSA, which is an important consideration when assessing for complications.

The likelihood of baseplate failure depends on the quality and quantity of preserved bone stock (Achors et al, 2022). Successful fixation requires adequate glenoid bone volume, a challenge particularly acute in patients with inflammatory arthritis and advanced arthropathy. A retrospective case-control study by DelBello et al (2020) utilised volumetric glenoid analysis through 3D computed tomography

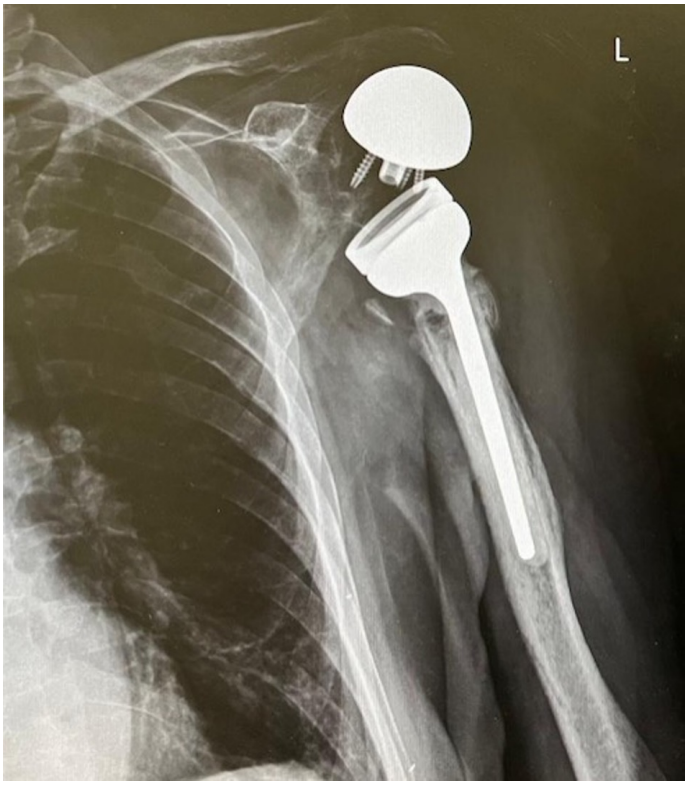

Fig. 5. X-ray demonstrating displacement baseplate and glenosphere in a reverse shoulder arthroplasty (RSA). Radiographs were obtained by authors with patient consent. The letter 'L' indicated the left side.

(CT) scans to establish thresholds predictive of baseplate failure. Their findings indicate that in females, a glenoid bone volume of 5 cc or less results in a 100% risk of baseplate failure, while in males, this threshold is 14 cc or less (DelBello et al, 2020).

A retrospective cohort study by Chen et al (2024) evaluates the nonoperative management of glenoid baseplate failure in RSA, identifying specific patient groups that may benefit from conservative strategies. Asymptomatic patients or those with minimal symptoms, particularly those with functional range of motion and low levels of pain, are prime candidates for nonoperative treatment. Additionally, older patients or those with lower activity levels are well-suited for nonoperative approaches, as their functional demands are less likely to be adversely affected by baseplate failure. This notion is further supported by Cvetanovich et al (2019), who conducted a retrospective review to compare outcomes based on various preoperative factors. Furthermore, patients with radiographic evidence of failure but without corresponding symptoms may also be appropriate candidates for nonoperative management, as highlighted in a retrospective study by DelBello et al (2020) that examines glenoid component positioning and its effects on outcomes. This tailored approach emphasises the importance of individual patient circumstances in determining optimal management strategies.

Scapular Notching

Scapular notching arises from mechanical impingement between the humeral component and the glenoid neck, leading to wear of the polyethylene component and surrounding bone osteolysis. The incidence of scapular notching is reported to range from 4.6% to 50.8%, with some studies indicating rates as high as 96% (Castagna et al, 2022), influenced by factors such as implant design and orientation. Fig. 6 depicts scapular notching and its effects on the glenoid and surrounding structures caused by mechanical impingement.

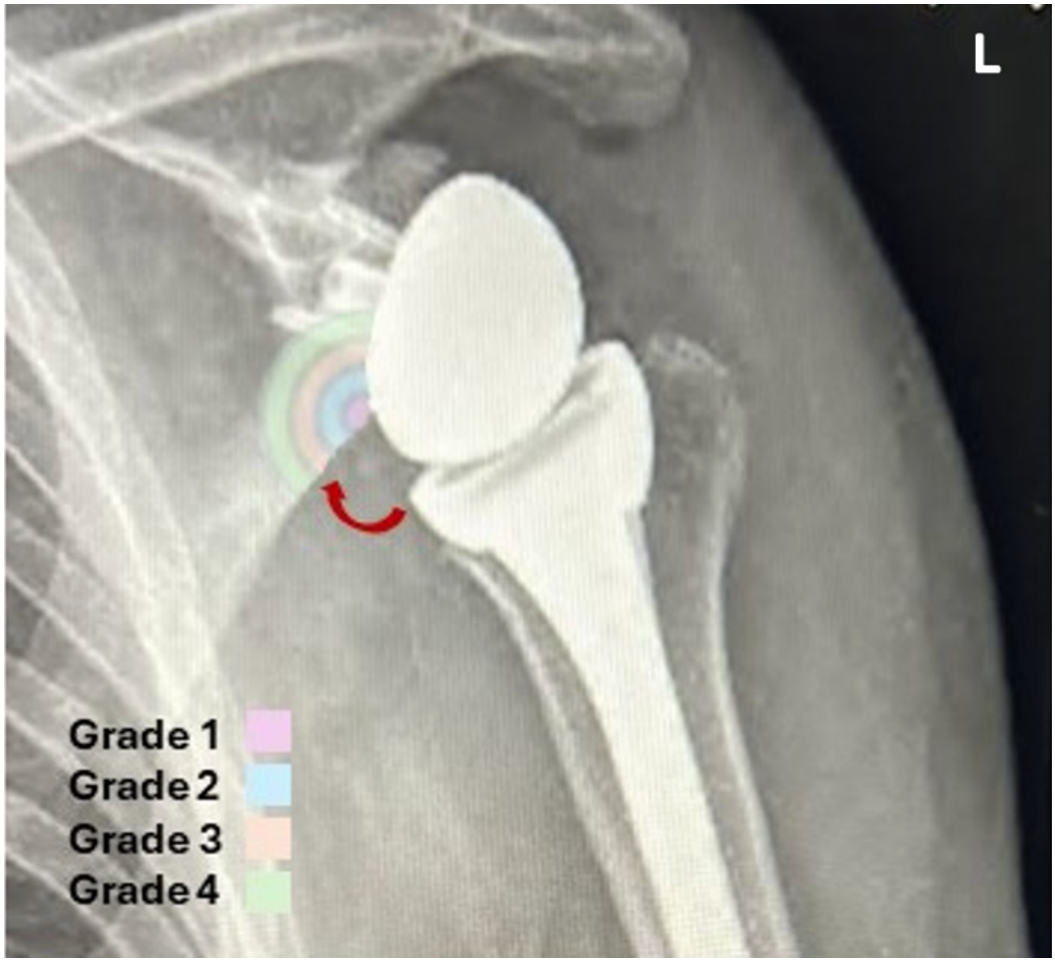

Fig. 6. Anteroposterior radiographs of RSA demonstrating Nerot Sirveaux's classification of inferior scapular notching. Grades 1 to 4 are illustrated using colour-coded regions: Grade 1 (minimal erosion), Grade 2 (notching reaching the inferior screw), Grade 3 (progression beyond the inferior screw), and Grade 4 (extensive notching affecting the glenoid baseplate). The red arrow highlights the site of inferior scapular notching. Radiographs were obtained with patient consent. Image created by authors using Canva Visual Suite (Version 2024, Canva Pty Ltd, Sydney, NSW, Australia)—https://www.canva.com. The letter 'L' indicated the left side.

The incidence of scapular notching in RSA is influenced by various design and placement factors of the implants. Critical determinants include the orientation, humeral and glenoid lateralisation, and the size of the glenosphere. Notably, a glenoid component designed with an inferior overhang can mitigate the risk of

notching by enhancing the impingement-free arc of rotation and effectively distalising the centre of rotation (COR). Moreover, ensuring appropriate lateralisation of both humeral and glenoid components, along with a meticulous selection of glenosphere size and orientation, is essential for optimal outcomes. A recent meta-analysis by Jang et al (2020) highlights the significance of these design considerations, demonstrating their critical role in improving clinical results following RSA.

Modern RSA implants and techniques, particularly those utilising onlay prostheses with increased humeral inclination in combination with a lateralised baseplate and eccentric glenosphere, may provide promise in reducing scapular notching. A Level III therapeutic study by Freislederer et al (2024) demonstrated a 15% reduction in scapular notching in comparison to groups using inlay components. These emerging designs may offer better range of motion and decreased complication rates, providing valuable insights into evolving implant strategies aimed at mitigating notching complications in RSA.

Scapular notching can ultimately lead to baseplate loosening and failure and is managed in the same way as for this complication.

Fractures and Deltoid Dysfunction

Acromion and spine of scapula fractures are recognised complications (ASES Complications of RSA Research Group et al, 2021). These fractures compromise the deltoid muscle, due to their critical points of muscle origin. RSA procedures involving distalisation of the humerus and medialisation of the COR, increase the mean arm length by approximately 2.5 cm (Werner et al, 2017). This increases tension and torque on the deltoid muscle.

The incidence of acromion and scapular spine fractures varies, with studies reporting rates between 0.8% and 11.2% (Cassidy et al, 2022). These fractures are more common in revision surgeries and in patients with poor bone quality (Nyffeler et al, 2020).

Clinically, patients often present with lateral shoulder pain and a significant decrease in shoulder function, characterised by an inability to elevate the arm due to the loss of deltoid muscle tension.

Non-operative management involves immobilisation and physical therapy, aiming to reduce pain and restore function gradually, aiming for union of the fracture. Acromion fractures however have a rate of non-union rate of 61.4% (Boltuch et al, 2022). Surgical intervention may be necessary for displaced fractures or those that fail conservative treatment and include open reduction and internal fixation (ORIF) to stabilise the fracture and restore deltoid function (Yu et al, 2024).

Neurovascular Injury

Neurovascular complications are relatively rare with an overall incidence ranging from 2% to 5% (Kammel et al, 2024). Nerve injuries are more frequently observed, particularly the axillary nerve, with an incidence reported between 1% and 4% (Vajapey et al, 2021). Axillary nerve injury results primarily in deltoid weakness or paralysis. Limited literature exists that comments on vascular injuries,

however, vascular injuries can lead to hematoma formation, and ischemia, and may necessitate emergency vascular repair (Ntola and Hardcastle, 2023).

For nerve injury, initial management may include physical therapy and monitoring for spontaneous recovery, which is possible in cases of neurapraxia (Zhou et al, 2015). If there is no improvement over time, worsening neurology or neuropathic pain, surgical exploration and neurolysis or nerve repair or grafting may be required (Zhou et al, 2015)

Vascular complications may require interventions ranging from careful monitoring and anticoagulation therapy to thrombectomy or vascular repair. Early identification and management of these complications is crucial to preventing long-term deficits (Stefanou et al, 2024).

Strategies to Minimise the Need for Revisions

Minimising the need for revision surgery in RSA begins with identifying appropriate candidates through preoperative assessment. Patients with good deltoid function, intact or partially intact rotator cuffs, and adequate bone stock are generally more likely to experience successful outcomes. Avoiding RSA in patients who may not benefit, such as those with uncontrolled infections, poor bone quality, or significant soft tissue deficiencies, can help reduce revision rates (Yoon et al, 2023).

The accurate positioning of the glenoid component is critical, as this can prevent complications like scapular notching, instability, and glenoid loosening. In cases of bone loss, the use of augmented glenoid implants has shown promise in enhancing stability. Selecting cemented or press-fit stems based on bone quality is also crucial to secure the fixation of the humeral component and reduce the risk of loosening (Yoon et al, 2023). Advances in implant design, such as modular components, augmented glenoid baseplates, and lateralisation options, allow for a more tailored approach to each patient's unique anatomical challenges, thereby potentially minimising implant-related complications. Designs that accommodate bone loss with options for variable angulation and fixation can also contribute to reducing the risk of failure (Berhouet et al, 2022; Yoon et al, 2023).

In patients with bone loss identified during primary RSA, bone grafting can create a stronger foundation for implant fixation, which may help distribute forces more evenly and thus reduce wear and loosening over time. The use of patient-specific implants or augmented components in complex cases is another strategy that holds promise for reducing revision rates (Lädermann et al, 2015; Yoon et al, 2023). Proper tensioning and balancing of the deltoid and surrounding soft tissues are vital aspects of RSA, with careful soft tissue handling during the primary procedure helping to mitigate the risks of dislocation and instability. In addition, preoperative strengthening of the deltoid muscle in RSA candidates can enhance postoperative stability and function, which may lower the likelihood of revision surgery due to instability (Schwartz et al, 2014; Yoon et al, 2023).

Infection control is another critical aspect, with meticulous sterile technique and adherence to prophylactic antibiotic protocols being essential to reduce the risk of PJIs. For patients at a higher risk of infection, such as those who are immunocompromised, staged procedures or postoperative suppressive antibiotic therapy may be

considered to minimise infection-related revision rates (Katz et al, 2016; Yoon et al, 2023). Comprehensive preoperative planning, including detailed imaging like CT scans with 3D reconstruction, enables a thorough understanding of the patient's anatomy and facilitates the anticipation of surgical challenges. Furthermore, virtual planning and navigation-assisted surgery can aid in precise component placement, which can help avoid positioning-related failures that might otherwise necessitate revision (Yoon et al, 2023).

Surgical Salvage

Revision options for failed RSA present significant challenges and complications but can be effective in restoring function and alleviating pain under appropriate conditions (Boileau, 2016). Replacing failed components with new RSA implants has shown success in patients with adequate bone stock and limited infection risk. However, issues such as bone loss from previous surgeries, infection risk from repeated interventions, and complications related to scar tissue and altered anatomy continue to complicate these procedures (Rugg et al, 2019; Shah et al, 2020). When managed carefully, bone grafting or augmented components can improve stability and restore function in some patients.

Hemiarthroplasty can effectively relieve pain in cases with minimal rotator cuff deficiency, although it may provide limited functional improvement for patients with extensive cuff pathology. While it does not address the glenoid, it can be a viable option for certain patients, balancing pain relief and functional goals (Boileau, 2016).

Resection arthroplasty, while typically reserved as a last resort, can offer pain relief by removing infected or failing prosthetic components. Although it results in significant functional limitations, it may provide stability in cases where joint preservation is no longer viable (Rugg et al, 2019; Shah et al, 2020).

The Allograft-Prosthesis Composite (APC) technique has shown promise in reconstructing major bone defects, especially with advancements in graft matching and fixation. Although technically demanding, recent reports highlight improved outcomes with proper graft integration and low infection rates in specialized centres (Boileau, 2016; Jacquot et al, 2023).

Scapulohumeral arthrodesis, though it sacrifices mobility, can provide reliable stability and pain relief, particularly in patients with extensive soft tissue damage. Technical refinements and careful patient selection have reduced non-union rates in recent studies, making it a viable option for select cases (Kamineni et al, 2019).

Suggested Patient Selection

As detailed in Fig. 7, the suggested pathway for patient selection outlines key assessment criteria and prosthesis selection factors. This includes evaluating the primary diagnosis, functional limitations, imaging findings, and overall bone quality.

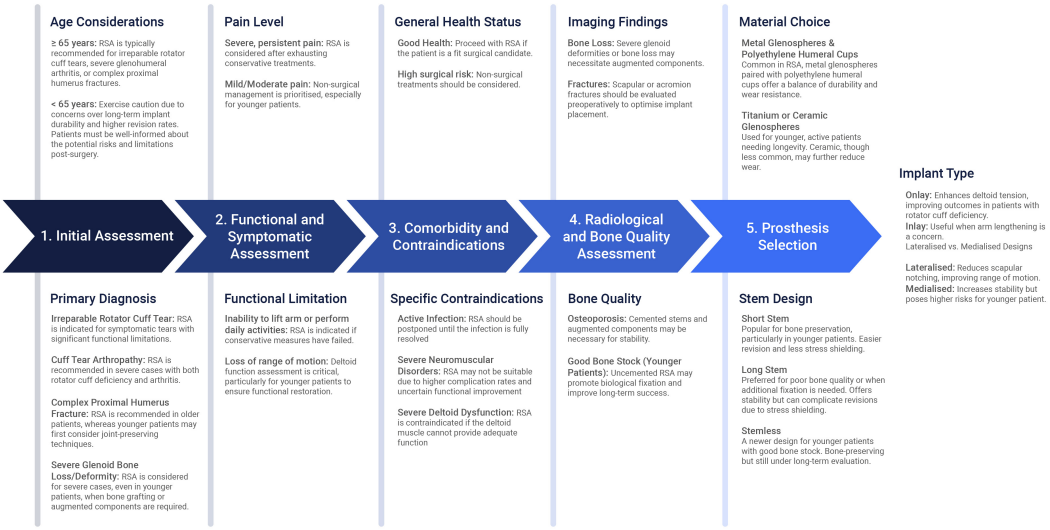

Fig. 7. Suggested pathway for patient selection in reverse shoulder arthroplasty, outlining assessment and prosthesis selection criteria. Figure created by the authors using Adobe Illustrator (Version 27.9, Adobe Inc., San Jose, CA, USA).

Is RSA Overused?

While the clinical benefits of RSA are well-documented, there is an emerging concern within the orthopaedic community regarding the potential overuse of this procedure, particularly in patient populations where the long-term outcomes remain uncertain. The expansion of RSA indications to include younger, more active patients presents significant challenges. These patients, due to their higher activity levels, may be at increased risk for complications such as prosthetic instability and earlier implant failure, which could necessitate complex and costly revision surgeries. Mollon et al (2017) highlighted these risks, particularly in younger cohorts, where the long-term data on RSA remains sparse and inconclusive. The enthusiasm for RSA's short-term success should not overshadow the need for rigorous evaluation of its long-term viability, particularly when alternative, less invasive treatments may suffice. Non-surgical approaches, including physical therapy, intra-articular corticosteroid or platelet-rich plasma (PRP) injections, and minimally invasive procedures such as arthroscopic debridement, have shown promise in managing shoulder symptoms for younger patients without necessitating RSA. Additionally, partial shoulder arthroplasty may offer a less invasive surgical option that retains more native anatomy (Valsamis et al, 2023).

Consequently, there is a pressing need for caution to prevent the overuse of RSA, ensuring that its application remains judicious, evidence-based, and tailored to the specific needs of each patient (Boileau, 2016; Chelli et al, 2022). In mitigating the potential for overuse, more formal guidelines for patient selection should be established, particularly for younger, more active patients who may not benefit from RSA in the long term. Evidence-based practice should guide decision-making, ensuring that RSA is reserved for cases where conservative treatments have failed, and the benefits clearly outweigh the risks. We suggest that these guidelines be

supported by high-quality research, including randomized controlled trials, to refine selection criteria and avoid the inappropriate application of RSA.

Current Evidence on Long-Term Outcomes

RSA has consistently shown improvements in pain relief and shoulder function, as observed in both short- and mid-term follow-ups (Doyle et al, 2023). However, the evidence for these outcomes over the long term largely stems from lower levels of evidence, primarily prospective cohort studies and retrospective case series, classified as Level III and IV evidence (Ernstbrunner et al, 2019; Galvin et al, 2022). A systematic review analysing 20 studies with at least five years of follow-up across 1,591 shoulders reported high patient satisfaction rates of 88%, alongside significant functional improvements, commonly assessed through the Constant Murley score (Doyle et al, 2023).

Despite these encouraging findings, the majority of long-term studies present limitations. Cohort studies, classified as Level III evidence, lack randomisation, which introduces selection bias. Healthier patients or those with less severe shoulder dysfunction are more likely to have favourable outcomes, thus skewing results (Cogan et al, 2023). Without randomised control groups, it is difficult to establish causality or make direct comparisons between surgical techniques and prosthesis designs (Schoch et al, 2021). Retrospective case series, as Level IV evidence, are especially vulnerable to bias, given that they are not prospectively designed and often lack control groups. Excluding patients who undergo revision surgery or experience complications may lead to an overly optimistic view of RSA outcomes. Furthermore, these studies may not capture all complications systematically, complicating efforts to fully understand issues like scapular notching or implant loosening (Jang et al, 2020; Simovitch et al, 2019).

Complication rates in long-term studies highlight several adverse outcomes that tend to increase over time. Scapular notching, for instance, is reported in up to 30.9% of cases, though its functional impact is inconsistently documented (Simovitch et al, 2019). While some studies suggest it has minimal effect on outcomes, others indicate that more severe notching may reduce the range of motion and heighten revision risk (Kohut et al, 2022). Additionally, prosthetic instability and glenoid baseplate loosening become more prevalent with extended follow-ups, particularly in patients with poor bone quality (Doyle et al, 2023). Reported revision rates rise from 4.9% to 14% when follow-up extends beyond ten years (Schoch et al, 2021).

The limitations in current study designs are also noteworthy. Randomised controlled trials (RCTs), regarded as Level I evidence, are absent in RSA literature, largely due to ethical and logistical challenges (Cogan et al, 2023). Ethical concerns arise when randomisation involves withholding surgery from patients with severe shoulder dysfunction, making it difficult to conduct true RCTs in this field. Additionally, both patient and surgeon preferences for RSA, given its proven efficacy in pain relief and functional improvement, can hinder randomisation efforts. The long-term follow-up required in these studies is resource-intensive, often result-

ing in high dropout rates, especially among patients who have undergone revisions or experienced complications. This introduces survivorship bias, as only those with favourable outcomes are likely to remain in the study (Doyle et al, 2023).

Other limitations include the prevalence of small sample sizes and single-centre data in long-term studies. These factors restrict the generalisability of findings, as outcomes reported from single centres with limited patient numbers may not represent broader patient populations or surgical techniques. Additionally, there is significant variability in how functional outcomes and complications are reported, complicating comparisons across studies. While many studies document pain and range of motion improvements, they often fail to uniformly report complications like scapular notching, prosthetic loosening, or revision rates (Ernstbrunner et al, 2019).

To strengthen the evidence base for RSA, several areas warrant further investigation. Although conducting RCTs in RSA poses challenges, studies comparing different implant designs (e.g., lateralised vs. medialised) and surgical techniques are still needed. These trials should focus on long-term functional outcomes, complications, and patient satisfaction to provide higher-quality evidence for clinical practice (Doyle et al, 2023). Additionally, as RSA designs evolve, long-term studies are necessary to assess the impact of specific implant features—such as lateralised glenoid components or modular systems—on outcomes like scapular notching and implant longevity. Comparative studies with large patient cohorts could clarify which design features offer the greatest long-term benefits (Ernstbrunner et al, 2019).

Given the increasing use of RSA in younger, more active patients, it is also critical to study how increased activity levels impact implant longevity and complication rates. Long-term follow-up focusing on this demographic would provide valuable insights into the durability of RSA in younger patients (Nielsen et al, 2022). Lastly, future studies should adopt consistent reporting standards that encompass all complications, including prosthetic loosening, scapular notching, and infections. Comprehensive documentation of these complications is crucial to understanding their impact on long-term function and the need for revision surgery (Spiry et al, 2021).

Conclusion

RSA has revolutionised the management of complex shoulder conditions, offering substantial improvements in pain relief, functionality, and quality of life for many patients. The procedure's widespread adoption globally is a testament to its efficacy in treating severe shoulder pathologies. However, the rapid increase in RSA procedures, particularly among younger and more active patient populations, necessitates a more measured and cautious approach to its use.

The expansion of RSA indications must be grounded in a cautious and evidence-based strategy, as the long-term data supporting its use in younger populations and in less conventional indications remain limited. The associated risks of RSA, including instability, infection, and baseplate failure, underscore the need for con-

tinued innovation in implant design, surgical techniques, and the importance of stringent patient selection criteria.

To ensure that RSA continues to deliver optimal outcomes, the orthopaedic community must prioritise high-quality, long-term research. This research should focus on implant durability, particularly in younger, more active patients, and in diverse patient populations. Randomised controlled trials (RCTs) and comprehensive cohort studies examining long-term functional outcomes, complication rates, and patient satisfaction are essential to provide robust evidence that can guide clinical decision-making. This approach will mitigate the risks of overuse and ensure that RSA remains a reliable and effective treatment option, tailored to the needs of each individual patient. Ultimately, the future of RSA hinges on balancing its promising benefits with a cautious, evidence-based expansion of its indications, ensuring that it continues to enhance patient outcomes without compromising long-term safety and efficacy.

Key Points

- Reverse shoulder arthroplasty (RSA) was initially developed to treat cuff tear arthropathy in elderly patients, enhancing shoulder function and stability by modifying joint biomechanics.
- RSA usage has significantly increased, with its indications expanding to include complex shoulder fractures, glenoid bone loss, and revision surgeries.
- Despite advancements in surgical techniques and prosthetic designs, complications such as instability, infection, and baseplate failure remain considerable concerns.
- There is growing concern about the overuse of RSA, particularly in younger, more active patients, where long-term data on durability and outcomes are limited.
- The article highlights the importance of cautious patient selection, evidence-based decision-making, and further long-term studies to better understand RSA's efficacy and safety.

Availability of Data and Materials

All the data of this study are included in this article.

Author Contributions

PB and AS designed the research study. PB and AS performed the research. PB, MR and AS analysed the data. PB drafted the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Verbal consent was obtained from patients for the use of anonymised radiographs.

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Conflict of Interest

The authors declare no conflict of interest.

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