

The «SPA-CE» Classification for Glenoid Bone Loss in Reverse Shoulder Arthroplasty: A CT-Based Analysis of 211 Shoulders

Dmitry A. Samkovich

`dmitry.samkovitch@gmail.com`

State Budgetary Institution of public health "City Clinical Hospital № 31 of the Moscow Health

Georgii A. Airapetov

State Budgetary Institution of public health "City Clinical Hospital № 31 of the Moscow Health

Vadim F. Naidanov

State Budgetary Institution of public health "City Clinical Hospital № 31 of the Moscow Health

Ivan A. Dmitrov

State Budgetary Institution of public health "City Clinical Hospital № 31 of the Moscow Health

Alexey P. Prizov

«Peoples' Friendship University of Russia»

Asadula R. Abasov

«Peoples' Friendship University of Russia»

Armen A. Daniliyants

State Budgetary Institution of public health "City Clinical Hospital № 31 of the Moscow Health

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Abstract

Background:

Glenoid bone loss represents a major challenge in primary reverse shoulder arthroplasty (RSA), directly influencing implant fixation, positioning, and reconstructive strategy. Existing classification systems describe glenoid morphology but do not provide a unified framework for treatment-oriented decision-making. The SPA-CE classification was developed as a CT-based system integrating defect depth, location, and version abnormality.

Methods:

A retrospective analysis of 211 consecutive primary RSA procedures was performed. Preoperative CT scans were used to classify glenoid morphology according to the SPA-CE system and the Walch classification. Reconstructive strategies were analyzed in relation to SPA-CE types. The distribution of morphologic patterns and their association with surgical techniques and underlying diagnosis were assessed.

Results:

The most common SPA-CE pattern was simple central (SC), observed in 62.1% of cases. Overall, simple (S) defects predominated (75.4%), whereas plastic (P) defects accounted for 24.2% and advanced (A) defects were rare (0.5%). Defects managed without structural reconstruction (SC and SEI) accounted for 73.9% of shoulders, whereas 1.4% required version correction without lateralization (SEII), 24.2% required lateralization (plastic types), and 0.5% required patient-specific reconstruction. A consistent relationship was observed between SPA-CE types and reconstructive strategies. In contrast, substantial variability in SPA-CE patterns was identified within individual Walch groups, particularly in Walch B2 glenoids.

Underlying diagnosis influenced defect morphology: post-traumatic conditions, fractures, and rotator cuff tears were predominantly associated with SC defects, whereas osteoarthritis demonstrated the widest distribution of SPA-CE patterns, including complex and reconstructively demanding defects.

Conclusion:

The SPA-CE classification provides a structured, CT-based and treatment-oriented framework for the assessment of glenoid bone loss in RSA. It demonstrates a consistent relationship with reconstructive strategies and may improve preoperative planning and surgical decision-making.

Introduction

Primary reverse shoulder arthroplasty (RSA) has become an established treatment option for several common degenerative conditions of the shoulder. Although reverse implants were initially introduced for

cuff tear arthropathy, their use has progressively expanded to other primary settings, particularly primary glenohumeral osteoarthritis with rotator cuff insufficiency and selected cases of primary osteoarthritis with complex glenoid deformity. As indications have broadened, primary RSA has become an increasingly important procedure in contemporary shoulder arthroplasty practice, with consistently favorable pain relief and functional improvement reported across multiple etiologic groups [1, 2].

In primary reverse shoulder arthroplasty, successful fixation and positioning of the glenoid baseplate are critical determinants of implant stability and long-term construct survival. Inadequate bone support, residual version deformity, or non-anatomic placement of the glenoid component may compromise baseplate fixation and increase mechanical stress at the bone–implant interface [3, 4]. In addition, restoration of glenoid version, inclination, and joint line position has important implications for implant biomechanics, impingement-free range of motion, and overall shoulder function [5, 6]. For this reason, accurate assessment of glenoid morphology and appropriate reconstruction of bone loss represent central steps in preoperative planning and intraoperative decision-making during primary RSA.

Glenoid bone loss is a common finding in patients undergoing shoulder arthroplasty and represents a substantial challenge in primary reverse shoulder arthroplasty. Reported prevalence rates vary according to the underlying pathology and the classification criteria used, but clinically relevant glenoid deficiency has been described in up to 39%–40% of arthroplasty candidates [7, 8]. The pattern of bone loss may be central or peripheral and is frequently associated with abnormal glenoid version, altered joint line position, and loss of native bone stock available for baseplate support [9]. As a result, glenoid bone loss is not merely an anatomic observation but a clinically meaningful variable that directly influences implant choice, reconstructive complexity, and the technical demands of the procedure.

Several classification systems have been proposed to describe glenoid morphology and bone loss in shoulder arthroplasty. The Walch classification remains the most widely recognized system for primary glenohumeral osteoarthritis and is based on glenoid version, posterior wear, and humeral head subluxation [10]. In the setting of cuff tear arthropathy, the Favard classification has also been used to characterize superior glenoid erosion patterns [11]. These systems have substantially improved the radiographic description of glenoid deformity and remain valuable for communication and morphologic assessment. However, they were not specifically designed to support reconstructive planning in primary reverse shoulder arthroplasty. In particular, they do not provide a unified framework that simultaneously incorporates the depth of bone loss, its topographic location, and the degree of version correction required to restore a stable and implantable glenoid surface. As a result, morphologic description and reconstructive decision-making often remain only partially aligned in routine surgical practice.

A variety of reconstructive techniques have been described to address glenoid bone loss in reverse shoulder arthroplasty. These include eccentric reaming for minor version correction, structural bone grafting to restore bone stock and lateralize the joint line, metal augmentation to compensate for contained or segmental defects, and patient-specific or custom implants for more advanced bone loss [12–15]. Although each of these strategies may be appropriate in selected cases, their indications

depend on several interrelated morphologic factors, including the depth of bone loss, the location of the defect, and the magnitude of version abnormality. In clinical practice, however, there remains no widely adopted framework that integrates these variables into a single practical system for preoperative planning and intraoperative decision-making.

Given the high prevalence and surgical relevance of glenoid bone loss in primary reverse shoulder arthroplasty, there remains a need for a practical CT-based framework that links morphologic assessment with reconstructive strategy. The SPA-CE classification was developed to address this need by integrating three clinically relevant parameters of glenoid deficiency: defect depth, defect location, and the degree of version abnormality. In addition to providing a structured morphologic description, this framework was designed to support treatment-oriented surgical planning in primary reverse shoulder arthroplasty. The purpose of the present study was to analyze the distribution of SPA-CE glenoid patterns in a consecutive series of 211 shoulders undergoing primary reverse shoulder arthroplasty and to describe their corresponding reconstructive characteristics.

Materials and methods

Study design

This study was designed as a retrospective observational analysis of a consecutive single-center series of patients who underwent primary reverse shoulder arthroplasty between 2023 and 2025.

All consecutive primary procedures with available preoperative computed tomography (CT) imaging were included. The aim of the study was to evaluate glenoid morphology according to the SPA-CE classification and to assess the relationship between morphologic patterns and corresponding reconstructive strategies in routine clinical practice.

Patient selection.

A total of 211 primary reverse shoulder arthroplasties performed in 211 consecutive patients were included in the study. Inclusion criteria comprised primary reverse shoulder arthroplasty with available preoperative computed tomography (CT) imaging and complete operative documentation. Exclusion criteria included revision reverse shoulder arthroplasty, absence of preoperative CT imaging, and incomplete operative records.

The cohort included 154 women and 57 men. The median age at the time of surgery was 69 years (range, 35–85 years). A total of 111 shoulders were operated on the right side and 100 on the left.

The primary indications for surgery included glenohumeral osteoarthritis (n = 137), post-traumatic arthritis (n = 30), acute fractures (n = 18), rotator cuff tears (n = 13), and other (n = 13), including instability-related conditions and rheumatoid arthritis.

Imaging evaluation

Preoperative glenoid morphology was assessed using computed tomography (CT) in all included shoulders. Imaging evaluation was based on standard axial, coronal, and sagittal CT reconstructions, as well as three-dimensional (3D) reconstructions when available. All images were reviewed in DICOM format.

CT assessment was used to characterize glenoid bone loss morphology and to assign each case to a corresponding SPA-CE type. Particular attention was given to the depth of the defect, its topographic location, and the degree of glenoid version abnormality, as these variables form the basis of the SPA-CE classification.

SPA-CE classification

The SPA-CE classification is a CT-based system developed to characterize glenoid bone loss based on three sequentially assessed parameters: defect depth, defect location, and the degree of glenoid version abnormality.

The first component defines the depth and reconstructive significance of the defect and is categorized as Simple (S), Plastic (P), or Advanced (A). Type S (simple) describes a preserved joint line located lateral to the base of the coracoid process and does not require lateralization. Type P (plastic) describes a joint line located at the level of or medial to the base of the coracoid process, indicating bone loss requiring lateralization using structural grafting or metal augmentation. Type A (advanced) describes glenoid bone loss exceeding 15 mm, often associated with loss of anatomic landmarks, in which standard reconstructive techniques may be insufficient.

The second component defines defect location as Central (C) or Edge (E), depending on whether the bone loss is centrally located or involves the glenoid rim. In central (C) defects, version correction is not required.

The third component applies only to edge (E) defects and reflects the degree of glenoid version abnormality. Version is graded as I or II, corresponding to deformity of less than 15° and greater than 15°, respectively.

Each shoulder was assigned a composite SPA-CE type based on preoperative CT imaging. The classification combines defect depth (S/P/A), location (C/E), and, in the presence of edge (E) defects, the degree of version abnormality (I/II), resulting in types such as SC, SEI, SEII, PC, PEI, PEII, and A (Fig. 1).

Glenoid morphology was additionally classified according to the Walch classification. Classification was performed retrospectively by three independent observers. In cases of disagreement, the final classification was established by consensus.

Surgical reconstruction strategies

Reconstructive strategies were analyzed in relation to the corresponding SPA-CE classification type in each case. Surgical techniques were categorized according to the principal method used to address glenoid bone loss and/or version abnormality.

In shoulders classified as Simple (S), lateralization was not performed. In central defects (SC), standard baseplate implantation was carried out without additional reconstruction. In edge defects with moderate version abnormality (SEI), correction was achieved using eccentric reaming. In cases with severe version deformity (SEII), version correction was performed using wedge-shaped structural grafts or wedge-shaped metal augments without lateralization.

In Plastic (P) types, lateralization was performed in all cases. In central defects (PC), lateralization was achieved using cylindrical structural grafts or cylindrical metal augments. In edge defects with moderate version abnormality (PEI), lateralization was combined with eccentric reaming. In cases with severe version deformity (PEII), both lateralization and version correction were performed using wedge-shaped grafts or augments.

In Advanced (A) types, reconstruction was performed using patient-specific or custom-made components in cases where standard reconstructive techniques were not feasible.

The relationship between SPA-CE types and reconstructive strategies is summarized in Fig. 2.

Results

According to the Walch classification, type A glenoids accounted for the majority of cases, including A1 in 108 shoulders (51.2%) and A2 in 41 shoulders (19.4%). Type B glenoids were observed in 52 shoulders (24.6%), including B1 in 13 cases (6.2%), B2 in 30 cases (14.2%), and B3 in 9 cases (4.3%). More severe deformities were less common, with type C in 8 cases (3.8%) and type D in 2 cases (0.9%).

According to the SPA-CE classification, the most common pattern was simple central (SC), observed in 131 shoulders (62.1%). The second most frequent type was simple edge I (SEI), identified in 25 cases (11.8%). Less common patterns included plastic central (PC) in 18 shoulders (8.5%), plastic edge I (PEI) in 12 cases (5.7%), and plastic edge II (PEII) in 21 cases (10.0%). Severe edge deformities without lateralization (SEII) were rare and observed in 3 shoulders (1.4%), while advanced (A) defects were identified in only 1 case (0.5%). When grouped by reconstructive significance, simple (S) patterns predominated, accounting for 159 shoulders (75.4%), followed by plastic (P) types in 51 cases (24.2%), whereas advanced (A) defects were rare (0.5%). With respect to defect location, central (C) defects were more common than edge (E) defects (70.6% vs. 29.4%).

A consistent and treatment-oriented relationship was observed between SPA-CE classification types and the applied reconstructive strategies. Simple central (SC) and simple edge I (SEI) defects, accounting for

156 shoulders (73.9%), were managed without structural reconstruction. In contrast, simple edge II (SEII) defects (3 cases, 1.4%) required correction of significant version deformity using wedge-shaped grafts or augments, without lateralization. All plastic (P) defects, including plastic central (PC), plastic edge I (PEI), and plastic edge II (PEII) patterns (51 shoulders, 24.2%), were consistently associated with reconstruction with lateralization. The single advanced (A) case (0.5%) required patient-specific reconstruction, reflecting the inability to achieve stable fixation using standard techniques. Overall, each SPA-CE subtype corresponded to a distinct reconstructive approach, with no relevant overlap between treatment categories (Fig. 3).

A relationship was observed between Walch classification types and SPA-CE patterns. Glenoids classified as Walch A most commonly corresponded to central defects, including both simple central (SC) and plastic central (PC) patterns. In contrast, Walch B types were more frequently associated with edge defects, ranging from SEI to PEII depending on the severity of version abnormality and defect depth. More severe deformities (Walch C and D) were uncommon and corresponded to the most advanced patterns of glenoid bone loss. Notably, substantial variability in SPA-CE classification was observed within individual Walch groups, particularly in Walch B2 glenoids, which demonstrated the widest range of SPA-CE subtypes and corresponding reconstructive strategies. The detailed relationship between Walch classification, SPA-CE subtypes, and corresponding reconstructive strategies is presented in Table 1.

Table 1
Relationship between Walch classification, SPA-CE subtypes, and corresponding reconstructive strategies.

Walch	n	SPA-CE	n	Reconstructive strategy
A1	108	SC	106	No reconstruction
		SEI	2	Eccentric reaming
A2	41	SC	23	No reconstruction
		PC	18	Lateralization with cylindrical graft or augment
B1	13	SC	1	No reconstruction
		SEI	9	Eccentric reaming
		PEI	3	Lateralization + reaming
B2	30	SEI	13	Eccentric reaming
		SEII	2	Wedge graft or augment
		PEI	9	Lateralization + reaming
		PEII	6	Lateralization with wedge graft or augment
B3	9	SEI	1	Eccentric reaming
		SEII	1	Wedge graft or augment
		PEII	7	Lateralization with wedge graft or augment
C	8	PEII	7	Lateralization with wedge graft or augment
		A	1	Patient-specific reconstruction
D	2	SC	1	No reconstruction
		PEII	1	Lateralization with wedge graft or augment

An association between underlying diagnosis and glenoid morphology was observed. Post-traumatic conditions, acute fractures, and rotator cuff tears were predominantly associated with simple central (SC) defects, indicating the absence of significant glenoid bone loss in the majority of these cases.

In contrast, glenohumeral osteoarthritis demonstrated a substantially wider distribution of SPA-CE patterns, including both central and edge defects, as well as plastic and advanced types, reflecting a higher prevalence of clinically relevant glenoid bone loss (Fig. 4).

Discussion

The present study demonstrates that glenoid bone loss in primary reverse shoulder arthroplasty can be systematically described using the SPA-CE classification and that distinct morphologic patterns are consistently associated with specific reconstructive strategies. Most cases were represented by simpler defect configurations that could be managed without structural bone reconstruction, whereas more complex patterns required the use of grafts or augments. This consistent correspondence between morphology and surgical approach highlights the practical value of a structured, treatment-oriented classification system.

Importantly, the SPA-CE classification demonstrated a direct relationship between morphologic patterns and reconstructive strategy, which is not provided by existing descriptive classification systems.

The observed distribution of SPA-CE patterns provides insight into the typical morphology of glenoid bone loss encountered in primary reverse shoulder arthroplasty. The predominance of simple defect configurations suggests that, in most cases, glenoid deficiency does not require structural reconstruction. At the same time, the presence of edge defects indicates that version abnormality represents a relevant component of glenoid pathology and should be systematically considered during surgical planning.

In contrast, more complex patterns requiring structural reconstruction were less frequent but clinically significant, as they necessitate alternative reconstructive solutions and may influence implant selection. These findings emphasize that both defect depth and topography play a critical role in determining the surgical approach.

Existing classification systems for glenoid morphology, such as the Walch and Favard classifications, primarily focus on describing patterns of bone loss and glenoid version. While these systems provide valuable morphologic information, they do not directly guide reconstructive strategy in reverse shoulder arthroplasty.

Previous studies have emphasized the importance of addressing glenoid bone loss to achieve stable fixation and restore joint biomechanics, particularly in reverse shoulder arthroplasty (Airapetov et al., 2025 [16]). However, the choice of reconstructive technique often remains dependent on surgeon experience rather than a standardized morphologic framework.

In contrast, the SPA-CE classification incorporates parameters that are directly relevant to surgical decision-making, including defect depth, location, and version abnormality. This allows for a more practical interpretation of glenoid morphology, linking radiographic findings with specific reconstructive approaches. The consistent relationship observed in the present study between SPA-CE types and applied surgical techniques supports the concept of a treatment-oriented classification framework.

The SPA-CE classification has direct implications for surgical planning in primary reverse shoulder arthroplasty. By integrating defect depth, location, and version abnormality, it allows the surgeon to anticipate the need for bone reconstruction and to select an appropriate technique preoperatively.

In particular, the classification distinguishes cases that can be managed without bone grafting from those requiring structural reconstruction. It also differentiates between cylindrical and wedge-shaped reconstruction based on the presence and severity of version abnormality. This facilitates a more structured and reproducible approach to glenoid preparation and implant positioning.

As a result, the SPA-CE framework may reduce intraoperative uncertainty and support more consistent decision-making, especially in cases with complex glenoid morphology.

Beyond its role in surgical decision-making, the SPA-CE classification may also improve standardization of preoperative planning and facilitate communication between surgeons. A structured description of glenoid morphology allows for more consistent documentation and comparison of cases, which may be particularly relevant in multicenter studies and in the evaluation of different reconstructive techniques.

Study limitation

This study has several limitations. First, it was a retrospective analysis of a single-center cohort, which may limit the generalizability of the findings. Second, the SPA-CE classification was applied to the same dataset from which the underlying treatment patterns were derived, and therefore does not represent an independent validation. Third, interobserver and intraobserver reliability of the classification were not formally assessed. Finally, clinical and radiographic outcomes were not evaluated, and thus the impact of the classification on surgical results cannot be determined from the present study.

Future direction

Further studies are required to validate the SPA-CE classification in independent patient cohorts and to assess its reproducibility. Evaluation of interobserver and intraobserver reliability will be essential to determine its consistency in clinical practice. In addition, future research should investigate the relationship between SPA-CE classification types, surgical techniques, and clinical outcomes. Prospective studies may further clarify the role of the classification in preoperative planning and its potential impact on surgical decision-making.

Conclusion

The SPA-CE classification provides a structured, CT-based description of glenoid bone loss in primary reverse shoulder arthroplasty and demonstrates a consistent relationship with reconstructive strategies. By integrating key morphologic parameters, it may serve as a practical framework for treatment-oriented surgical planning.

Declarations

Conflict of Interest

All authors: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this manuscript, the authors used ChatGPT to assist with language editing and translation. The authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Abbreviations:

Not applicable.

Ethics approval and consent to participate:

This study was conducted in accordance with the Declaration of Helsinki. Data processing and analysis of surgical methods used in accordance with the developed classification were discussed and successfully approved by the «to be named after blind review» Ethics Committee (meeting number 7-2026) and the Ethics Committee of «to be named after blind review» (meeting number 273).

Each patient in the cohort was duly informed about the study. In accordance with the regional health department's internal order No. 558, electronic consent was obtained from patients for surgical interventions, the processing of personal data, and the disclosure of confidential medical information.

Consent for publication:

Not applicable.

Data availability:

The radiography dataset analysed during the current study are available from the corresponding author on reasonable request.

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Figures

Classification of Glenoid Bone Defects (SPA-CE)

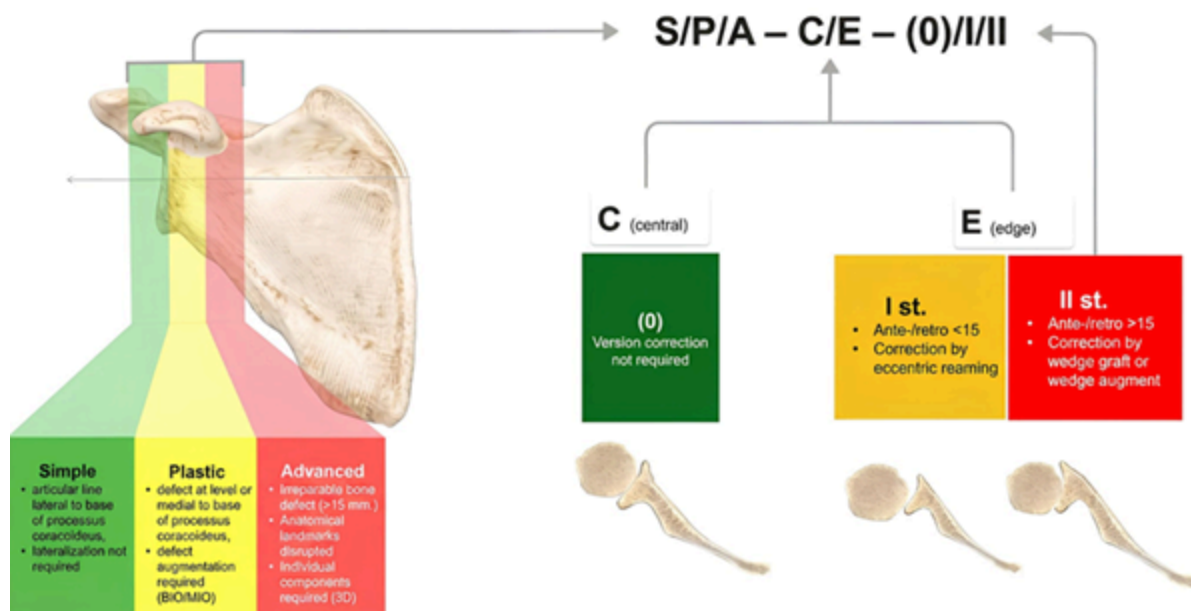


Figure 1

SPA-CE classification of glenoid bone defects based on defect depth (Simple, Plastic, Advanced), defect location (Central or Edge), and severity of glenoid version abnormality.

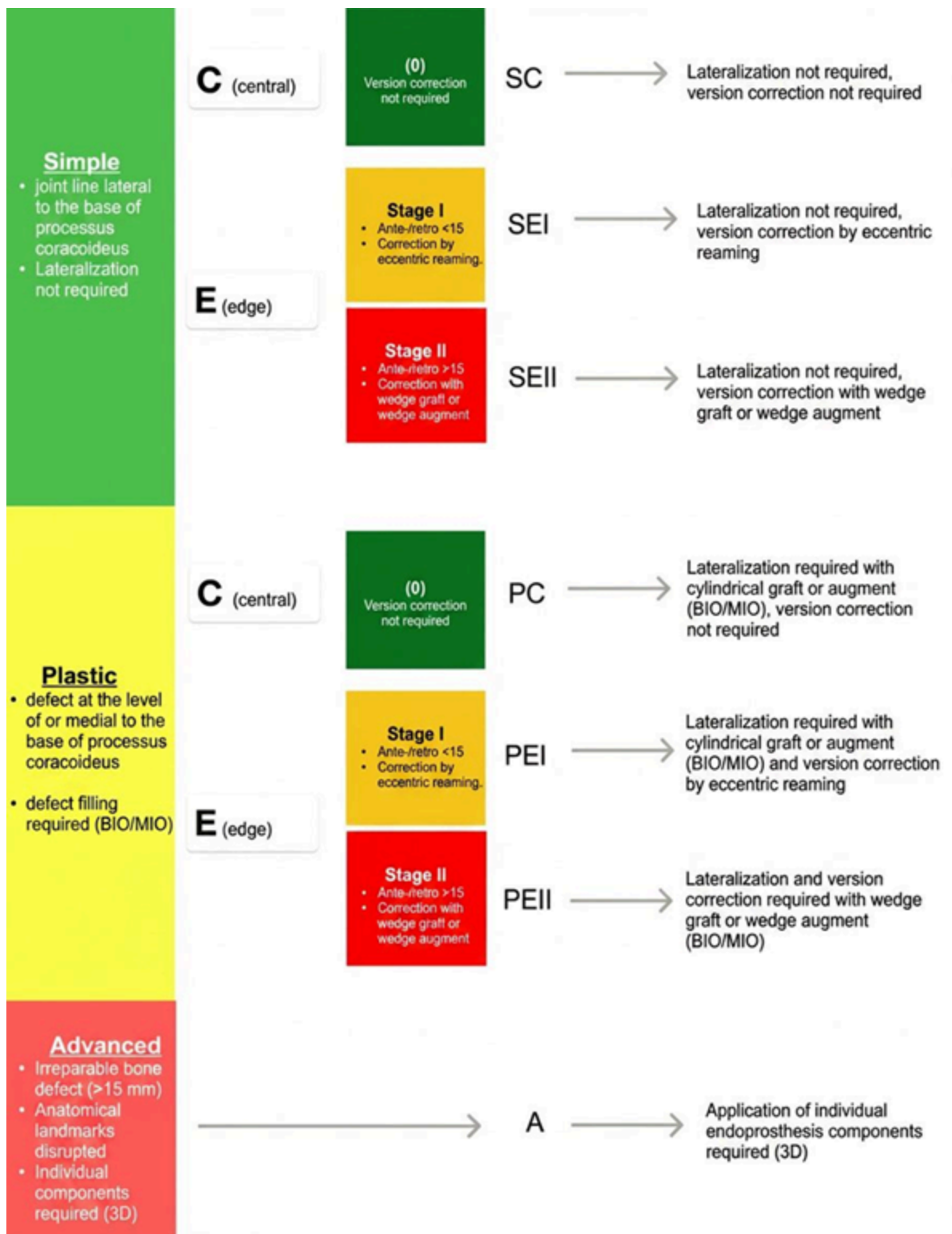


Figure 2

SPA-CE classification of glenoid bone defects based on defect depth (Simple, Plastic, Advanced), defect location (Central or Edge), and severity of glenoid version abnormality.

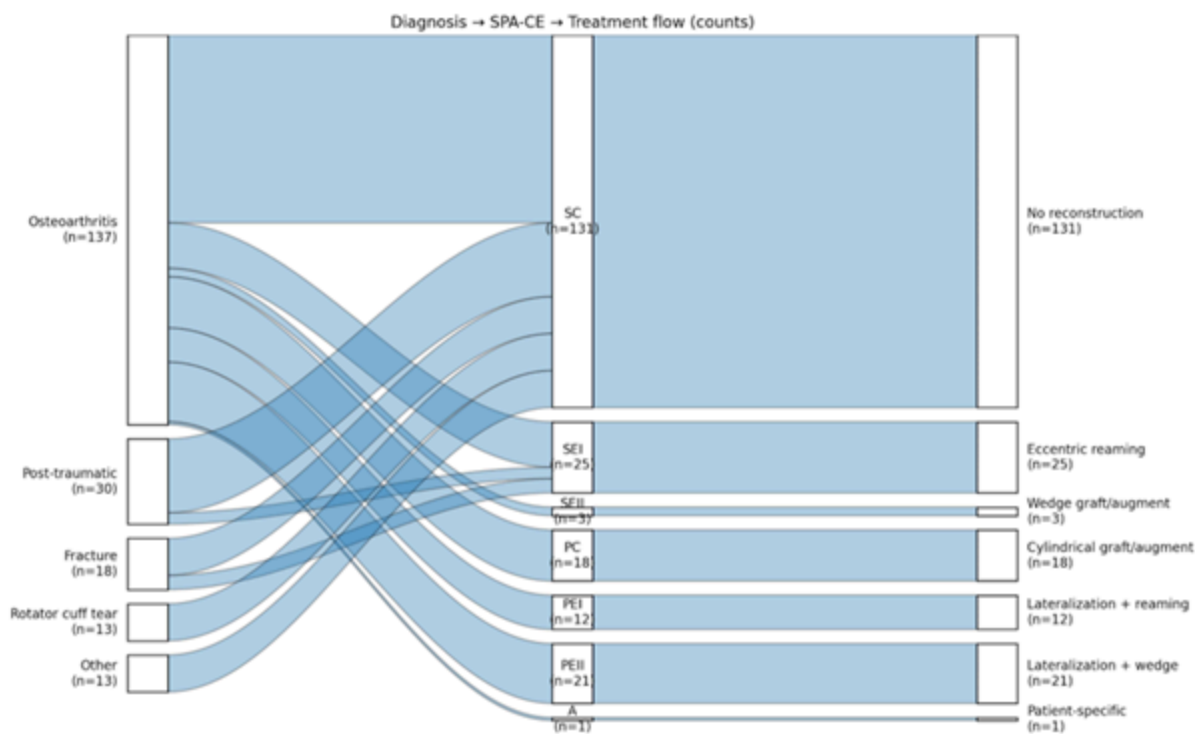


Figure 3

Flow diagram illustrating the relationship between underlying diagnosis, SPA-CE classification, and corresponding reconstructive strategies in reverse shoulder arthroplasty.

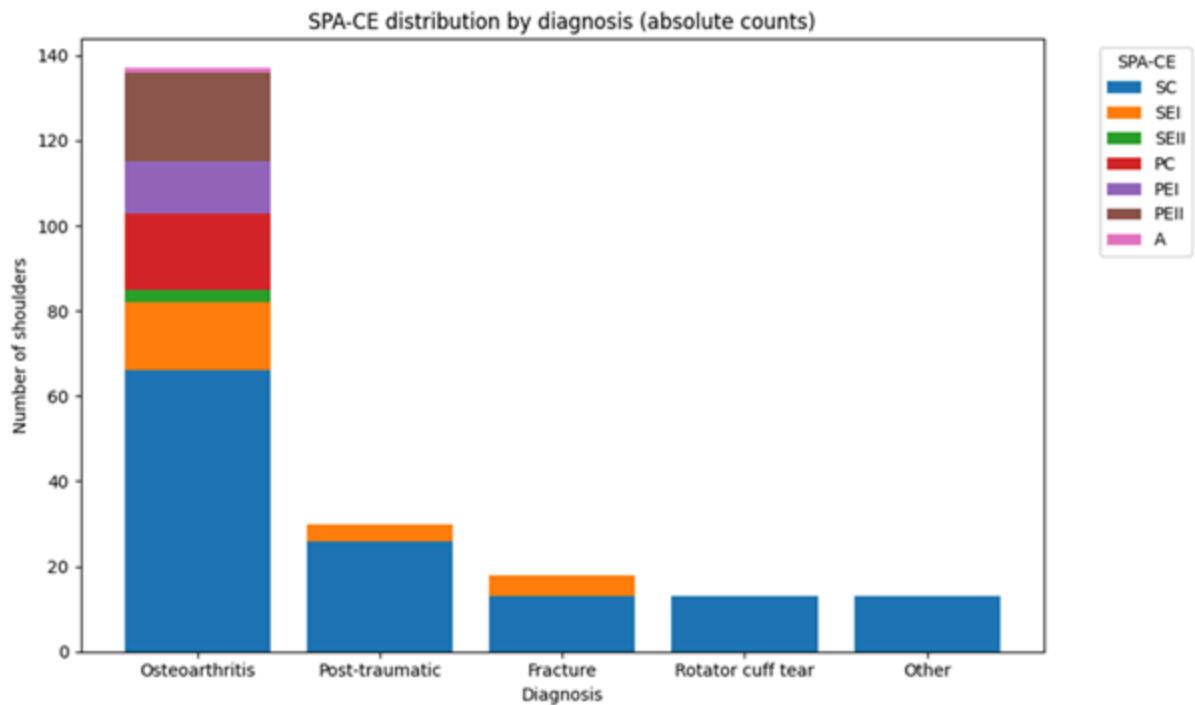


Figure 4

Absolute distribution of SPA-CE defect types according to underlying diagnosis.