European Journal of Orthopaedic Surgery & Traumatology (2019) 29:559–565
https://doi.org/10.1007/s00590-018-2313-9

ORIGINAL ARTICLE • SHOULDER - ARTHROPLASTY

Predetermining glenoid dimensions using the scapular dimensions

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Received: 29 August 2018 / Accepted: 7 October 2018 / Published online: 15 October 2018
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Abstract

Background Variations of morphology of the glenoid cavity have been previously reported. These influence the surgical reconstruction or arthroplasty of the shoulder. This study aims to study the variation of the shape of suprascapular notch, shape of glenoid cavity, dimensions of both the scapular and the glenoid cavity, and predict the glenoid dimensions from the scapular dimension parameters.

Materials and methods Adult-dried scapulae were collected. The shapes of each suprascapular notch and glenoid cavity were evaluated. The scapular height, scapular width, glenoid superoinferior distance, and glenoid anteroposterior distance were measured using a digital vernier caliper, and statistical analysis was conducted on the data that were obtained.

Results There were 264 scapulae included in this study (166 male and 98 female). Most of the glenoid cavities were pear shaped (69.7%). The two most common types of suprascapular notches were small depression notches (31.8%) and the absence of notches (25.8%). The mean ± SD of scapular height, scapular width, glenoid superoinferior distance, and glenoid anteroposterior distance were 148.2 ± 10.0, 108.1 ± 6.4, 37.1 ± 2.2, and 27.4 ± 2.1 mm, respectively, in the male samples and 133.0 ± 7.0, 97.0 ± 5.2, 33.2 ± 1.9, and 23.7 ± 1.7 mm, respectively, in the female samples. The male scapulae were significantly larger than the female scapulae (p value < 0.05). However, there were no differences between the male and female scapulae in terms of scapular index or glenoid index (p value > 0.05). Scapular height and width were significantly associated with both the glenoid superoinferior distance ($p = 0.0001$) and glenoid anteroposterior distance (p value = 0.0001).

Conclusion Scapular height and width can predict the dimensions of the glenoid. In cases of glenoid bone loss or shoulder arthroplasty, the native normal glenoid dimensions can be determined from the scapular dimensions as visualized using a true scapular anteroposterior radiograph. The surgeon can use these preoperative parameters when performing glenoid reconstruction or shoulder arthroplasty.

Keywords Scapula · Glenoid · Dimension · Morphology

Introduction

The scapula makes up the shoulder girdle in the appendicular skeleton and connects the upper limb to the axial skeleton. This wide flat bone is roughly triangular in shape and lies on the posterolateral aspect of the thoracic cage. The shortest and thinnest upper border is concave and extends from the medial angle to the base of the coracoid process. The suprascapular notch (SSN) is located on the upper border medial to the base of the coracoid process. The superior border of this notch is bridged by the superior transverse scapular ligament (STSL) to form a small foramen. The suprascapular nerve (SN) passes through the SSN inferior to the STSL to enter the supraspinous fossa. The contour

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of the notch has been shown as predisposing factor leading to SN entrapment [1–3]. The lateral angle of the scapula, known as the scapular head, is the thickest part. It is broad and bears the glenoid cavity. This shallow glenoid cavity articulates with the humeral head to form the most freely mobile glenohumeral joint. This anatomically unstable joint is stabilized by the rotator cuff muscles, tendons, ligaments, and the glenoid labrum, which provide mobility of the upper extremities and allow them to perform a versatile range of activities. The wide range of motion makes the joint prone to injury and arthropathy [4]. Variations of the morphology of the glenoid cavity have been previously reported. This information is useful for clinical application in shoulder arthroplasty [5, 6].

Treatment of late-stage shoulder arthrosis usually takes the form of arthroplasty. One previous study examined glenoid dimensions in order to ensure suitable implants designed for Japanese rotator cuff tear patients [7]. In addition, the relationships between glenoid size, inclination, and version are important guidelines for the orthopedic surgeon during shoulder reconstruction surgery [8].

Total shoulder arthroplasty and reverse total shoulder arthroplasty have become widely accepted treatments for glenohumeral arthrosis. One of the most common complications following shoulder arthroplasty is glenoid loosening [9]. Understanding the anatomy of the glenoid can prevent this problem. Primary glenoid osteoarthritis is usually associated with posterior glenoid wear [10], while inflammatory glenoid arthritis is associated with central erosion [9]. These conditions can distort the native anatomy of glenoid. In cases such as these, predetermining the dimensions of the glenoid is difficult or impossible. As mentioned above, glenoid bone loss can cause instability and recurrent shoulder dislocation [11]. The purposes of the current study were to: (a) study the morphology of the suprascapular notch and the glenoid cavity, (b) investigate the dimensions of the scapular body and glenoid cavity, and (c) predict the glenoid dimensions from the scapular dimension factors.

Materials and methods

Study design and sampling

This study was approved by the institute's Human Ethics Committee in compliance with the Declaration of Helsinki.

After excluding the bone with damaged scapular notch and glenoid cavity, all of 264 scapulae (166 males and 98 females) were chosen from the institute's Bone Collection Unit of the Department of Anatomy. The subjects' age range at the time of death in the male and female specimens were 25–84 and 29–92 years old, respectively. The shapes of each suprascapular notch and glenoid cavity were examined, classified, photographed, and recorded. The four metric parameters of each scapula (Fig. 1A, B) were taken in millimeter using a digital vernier caliper: (a) maximum scapular length

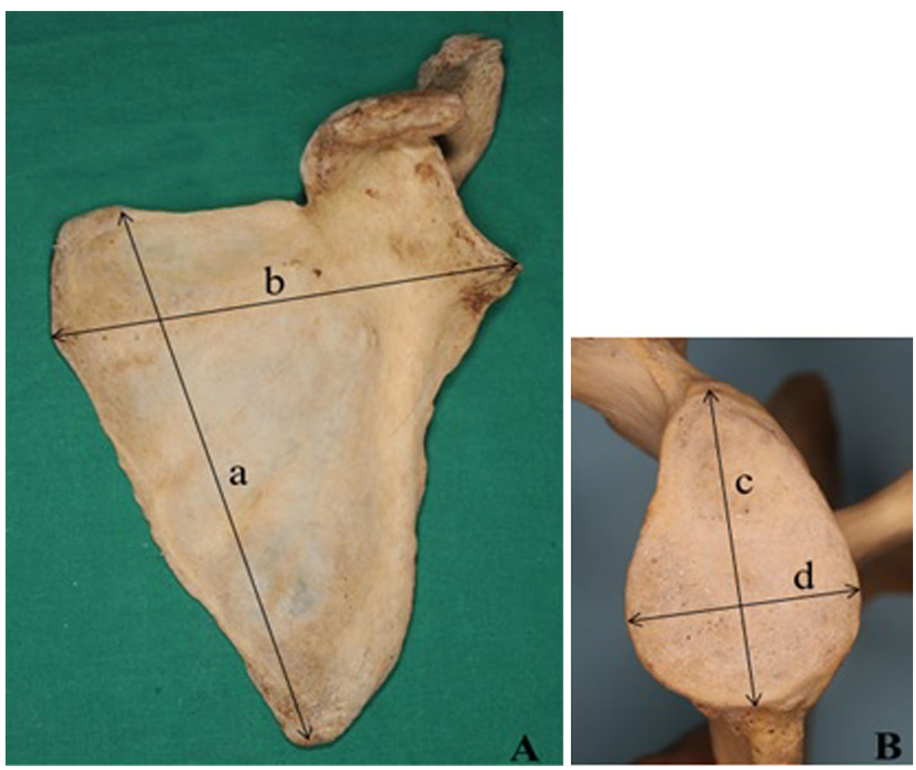

Fig. 1 Photographs of a left scapula showing: **A** anterior view, the maximum scapular length (a) and the maximum scapular breadth (b), and **B** the maximum glenoid cavity height (c) and the maximum glenoid cavity width (d)

(distance between the summit of superior angle and inferior angle), (b) maximum scapular breadth (distance between the lowest point of the glenoid and point of intersection of spine to the medial border of the scapular), (c) maximum glenoid cavity height (distance between the supraglenoid tubercle and the lowest point of the glenoid), and (d) maximum glenoid cavity width (distance between the anterior rim and posterior rim).

The scapular index (SI) and glenoid cavity index (GCI) were calculated as follows.

$$\mathrm{SI} = \frac{\text{maximum scapular breadth} \times 100\%}{\text{maximum scapular length}}$$

$$\mathrm{GCI} = \frac{\text{maximum glenoid cavity width} \times 100\%}{\text{maximum glenoid cavity height}}$$

In addition, the correlation study to investigate the dimensions of scapular body and glenoid cavity, and predict the glenoid dimension from the scapular dimension factors was analyzed and modeled using the linear regression statistics.

Statistical analysis

To ensure the study had a power of 80%, a sample size of 106 scapulae was needed to test the predictors (scapular width and height) for the dimension of the glenoid cavity (superoinferior and anteroposterior distance) [12]. The statistical significance level was set at 0.05. The anatomical measurements of scapular notch, scapular body, and glenoid were described. Univariate and multivariate linear regressions were calculated to formulate the predictive factors and the equations for glenoid dimensions. The data were analyzed using IBM SPSS Statistics (version 21, IBM Corporation, Armonk, New York).

Results

Anatomical variation of suprascapular notch types

As shown in Table 1 and Fig. 2, gross observation showed that the 264 scapulae exhibited various SSN shapes and they could be classified into seven types. Most of the variations were small depression (31.8%) and the absence of notches (25.8%).

Variations of the shape of glenoid cavity

The glenoid cavity shape was classified into three types according to the glenoid notch along the anterior margin of the cavity (Fig. 3) including pear (69.7%), inverted comma (23.5%), and oval shaped (6.8%).

Table 1 The type and frequency of the suprascapular notch

Type	Definition	Frequency (%)
1	No notch	25.8
2	Small depression	31.8
3	U shaped	18.9
4	V shaped	7.6
5	J shaped	8.3
6	Partial ossified STSL	5.7
7	Complete ossified STSL	1.9

STSL superior transverse scapular ligament

The scapular body and the glenoid cavity dimensions

The mean age ± SD for male and female specimens were 58.3 ± 16.4 and 57.4 ± 17.8 years, respectively. The overall mean ± SD of scapular height, scapular width, glenoid superoinferior distance, and glenoid anteroposterior distance of the male scapulae were 148.2 ± 10.0, 108.1 ± 6.4, 37.1 ± 2.2, and 27.4 ± 2.1 mm, respectively, and 133.0 ± 7.0, 97.0 ± 5.2, 33.2 ± 1.9, and 23.7 ± 1.7 mm, respectively, in the female specimens. The male scapular and glenoid dimensions were significantly larger than those of the female scapulae ($p<0.05$; Table 2). There was no significant difference in terms of scapular index [t (262) = 0.07, $p=0.94$] or glenoid index [t (262) = 0.09, $p=0.83$] between the male and female specimens.

Univariate linear regression analysis (Table 3) found that the scapular width and height were factors that were significantly associated with glenoid anteroposterior distance [$F(1, 262)=321.7$, $p=0.0001$, and $F(1, 262)=329.1$, $p=0.0001$, respectively]. Scapular width and height were also associated with the glenoid superoinferior distance [$F(1, 262)=222.7$, $p=0.0001$, and $F(1, 262)=235.2$, $p=0.0001$, respectively]. The R-squared values ranged from 0.52 to 0.61.

As shown in Table 4, multiple linear regressions were calculated to predict the glenoid dimensions in terms of both glenoid anteroposterior and superoinferior distances based on the scapular width and height. In terms of glenoid anteroposterior distance and superoinferior distance, a significant regression equations were found $F(2, 209)=230.3$, $p=0.0001$, R square = 0.69, and $F(2, 209)=150.8$, $p=0.0001$, R square = 0.59, respectively.

$$\begin{aligned}&\text{Glenoid anteroposterior distance (mm)}\\&= -3.52 + 0.14\,(\text{scapular width})\\&\quad + 0.10\,(\text{scapular height})\end{aligned}$$

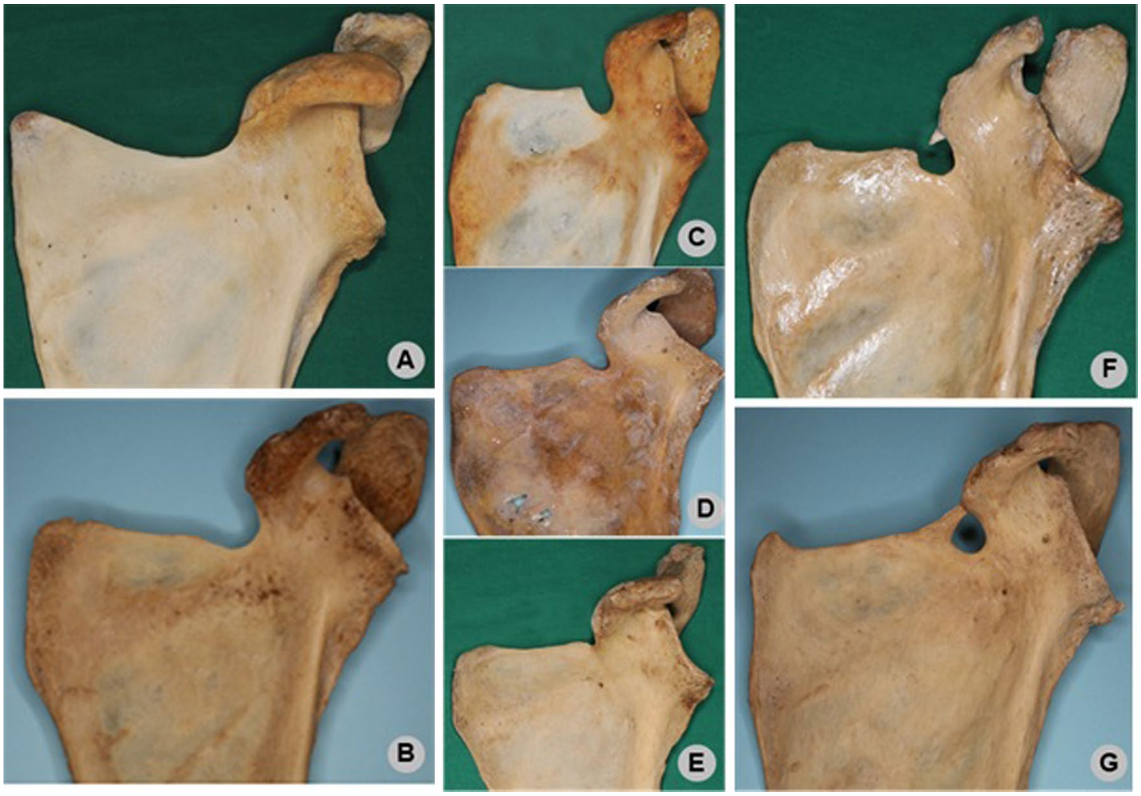

Fig. 2 Various types of scapular notch. **A** type 1, absence; **B** type 2, small depression; **C** type 3, U shape; **D** type 4, V shape; **E** type 5, J shape; **F** type 6, partially ossified superior transverse scapular ligament (STSL); **G** type 7, completely ossified STSL

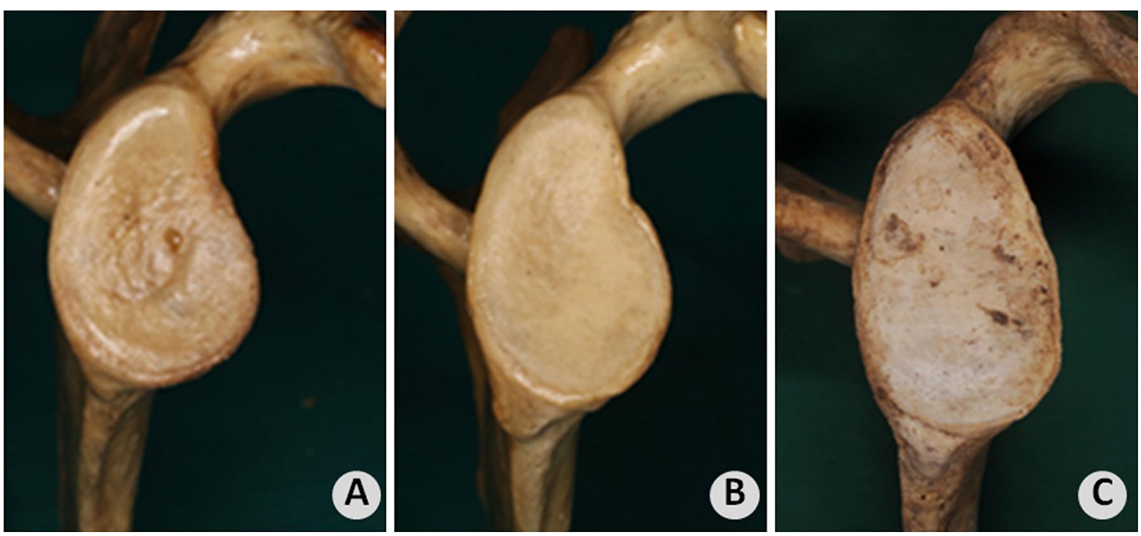

Fig. 3 Three types of glenoid cavity. **A** Pear shape, **B** inverted-comma shape, **C** oval shape

Table 2 The scapular and glenoid dimensions of male and female

	Scapular width		Scapular height		Glenoid anteroposterior distance		Glenoid superoinferior distance	
	Right	Left	Right	Left	Right	Left	Right	Left
Male (n = 83)	107.7 ± 6.0	108.5 ± 6.8	148.0 ± 10.0	148.4 ± 10.1	27.6 ± 2.1	27.2 ± 2.1	37.1 ± 2.2	37.1 ± 2.2
Female (n = 49)	97.1 ± 5.2	96.9 ± 5.3	132.7 ± 7.3	133.2 ± 6.8	23.9 ± 1.7	23.5 ± 1.7	33.3 ± 1.9	33.2 ± 1.9
p value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Mean difference (95% CI)	10.6 (8.3–12.9)	11.6 (9.1–14.1)	15.3 (11.7–19.0)	15.2 (11.9–18.5)	3.7 (2.9–4.5)	3.8 (3.0–4.5)	3.9 (3.0–4.7)	3.9 (3.1–4.7)

Values within table are mean ± standard deviation

CI confidence interval

Table 3 The univariate analyses

Parameters	β (95% CI)	p value
Glenoid anteroposterior distance		
Scapular width	0.78 (0.23–0.29)	0.0001
Scapular height	0.78 (0.16–0.20)	0.0001
Glenoid superoinferior distance		
Scapular width	0.72 (0.22–0.28)	0.0001
Scapular height	0.73 (0.15–0.20)	0.0001

CI confidence interval, β represents the coefficient of the linear regression

Table 4 Multivariate regression analyses

Parameters	β (95% CI)	p value
Glenoid anteroposterior distance		
Constant	− 3.52 (− 7.87 to − 6.25)	0.01
Scapular width	0.14 (0.10–0.18)	0.0001
Scapular height	0.10 (0.08–0.13)	0.0001
Glenoid superoinferior distance		
Constant	7.10 (3.83–10.36)	0.0001
Scapular width	0.13 (0.09–0.18)	0.0001
Scapular height	0.10 (0.07–0.14)	0.0001

CI confidence interval, β represents the coefficient of the linear regression

$$\begin{aligned}&\text{Glenoid superoinferior distance (mm)}\\&= 7.10 + 0.13\,(\text{scapular width})\\&\quad + 0.10\,(\text{scapular height})\end{aligned}$$

Discussion

Morphology of the suprascapular notch

Distribution of percentage of the various types of SSN has been classified in different populations in the literature. The present study classified the notch according to the inferior shape and the degree of ossification of the STSL. We found seven types of SSN, a result similar to that found in a Patiala population in India [13]. Rengachary et al. [14] categorized six types of SSN in which the most common SSN type was the symmetrical "U" shape (48%). The most common SSN type in Thais was the small depression (type 2) with the frequency of (31.8%). We also found that scapula without a discrete suprascapular notch in our population accounted for 25.8% of the specimens examined, which is close to the 28% reported by Wang et al. [15], in Chinese. Our study found that scapulae with J shaped and those with the absence of suprascapular notch types accounted for 8.3% and 25.8% of specimens, respectively. This contrasts with the results of a study by Patra et al. [13], which found these types to account for 39.09% and 4.54% of scapulae, respectively. These two types were not mentioned in Rengachary's observation [14].

The contour of the notch is thought to be a predisposing factor for suprascapular nerve entrapment [2, 14]. The absence of a suprascapular notch (type 1), including those scapulae with a small depression, or a partially/completely ossified STSL may irritate the suprascapular nerve leading to an increased risk of nerve compression. In the current study, the specimens that showed either partial or complete ossification of the STSL were mostly from subjects over 50 years of age, a finding similar to that reported by Inoue et al. [16]. However, two specimens in the partially ossified group were from subjects that were 45 and 47 years old. Clinicians should, thus, consider anatomic variation in terms of the shape of suprascapular notch when carrying out any endoscopic procedure or surgery involving the suprascapular notch region.

Shape of the glenoid cavity

The present study is the first to provide information on the shape of glenoid cavity in Thai subjects. Most of the glenoid cavities examined in this study were pear shaped (69.7%), while oval-shaped cavities were the least common, occurring in only 6.8% of cases. The current findings are similar to those of a previous report in an Indian population, which observed that pear-shaped glenoid cavities occurred most frequently (about 42–50%), while the least common were oval (about 13.6–20%) [5, 17–19].

In contrast, the incidences of oval-shaped glenoid cavities in some populations have been found to be higher than those found in Thai and Indian populations. For example, studies conducted in Turkish and German populations have found incidences of 72% [20] and 45%, respectively [21]. However, the triangular with notches along both the anterior and posterior border of the glenoid cavity found in Rajendra's [6] study was not observed in Thais. The shape of glenoid cavity and its clinical significance related to dislocation of the shoulder joint have been described. Prescher and Klumpen [21] found that an anterior sublabral recess can form when the glenoid notch is present along the anterior margin of the cavity (comma shaped). This recess can cause the rim of the cavity to be detached from the glenoid labrum, consequently decreasing the resistance against shoulder joint dislocation. Therefore, Rajendra et al. [6] proposed that the most stable type is the oval shaped which the glenoid labrum attaches all along the glenoid cavity.

The predictive dimensions of the scapula

The equation to predict the glenoid anteroposterior distance (mm) was $-3.52 + 0.14$ (scapular width) $+ 0.10$ (scapular height).

The equation to predict the glenoid superoinferior distance (mm) was $7.10 + 0.13$ (scapular width) $+0.10$ (scapular height).

Glenoid reconstruction is one treatment for glenoid bone loss causing recurrent shoulder dislocation. Glenoid bone loss can be assessed using the 3D reconstruction computerized tomography scanning of the shoulder [22], and the native normal glenoid dimensions can be predetermined using a calculation based on the true anteroposterior view of the scapula, allowing the surgeon to preoperatively determine the size and shape of the bone graft for glenoid reconstruction. In cases of shoulder arthroplasty, it is also easy to determine the size of glenoid using the scapular width and scapular height based on the true anteroposterior view of the shoulder radiography. Iannotti et al. [23] also reported that the glenoid size correlated well with the humeral head size. This would, thus, allow the surgeon to predetermine the prosthesis size. However, Wang et al. [24] reported on a suprascapular nerve injury that resulted from screw penetration into the suprascapular notch while fixing a glenoid prosthesis. Therefore, the screw should not point toward the suprascapular notch and it should not be so long as to cross the medial border of the coracoid process. Because small depression was found to be the most common type of suprascapular notch in the current study, we recommend checking the screw length and trajectory using intraoperative fluoroscopy.

Conclusions

The scapula plays a unique role in shoulder movement and stability. The most common types of suprascapular notch we found were absence of any notch and small depression. When fixing a screw in the glenoid, the screw should not point toward or extend beyond the base of the coracoid process. In cases of glenoid reconstruction surgery, native normal glenoid dimensions can be predetermined using the scapular height and width. This will help the surgeon to perform the operation without any complications.

Acknowledgements The authors would like to thank the Department of Anatomy, Faculty of Medicine of Khon Kaen University for providing the human scapulae. The authors would also like to acknowledge Dr. Dylan Southard for his assistance with the English-language presentation of this manuscript.

Authors contribution The authors participated in the design, execution, analysis, and writing up of the research.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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