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ORIGINAL ARTICLE

Reliability of preoperative conventional X-ray diagnostics for multifragmentary midclavicular fractures — a retrospective cohort study

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Abstract

Purpose The aim of this study was to evaluate the reliability of assessing preoperative conventional X-ray diagnostics in determining whether a comminuted clavicle fracture is present.

Methods A total of 326 patients with complete clinical and radiological documentation treated for a central clavicle fracture at the author's department between January 1, 2012, and June 30, 2023, were included. Among these, 73 were female, and 253 were male in a mean age of 37.5 ± 17 years.

Results On preoperative X-ray images or operation reports, 109 (33%) or 78 (24%) simple and 217 (67%) or 248 (76%) comminuted fractures were identified. Thity-one out of 248 comminuted fractures were only discovered intraoperatively, accounting for 13%. According to the AO classification on preoperative X-ray or operation reports, 109 or 78 fractures were classified as type A (33% or 24%), 51 or 45 as type B (16% or 14%), and 166 or 203 as type C (51% or 62%). For 40 patients, the discrepancy between the preoperative X-ray and the intraoperative fracture type led to a change in the surgical procedure. This represents 12% of the total cohort or 91% of the fractures that were classified differently preoperatively compared to intraoperatively. In these cases, fractures were treated with open reduction and angular stable plate osteosynthesis instead of the preoperatively planned elastic stable intramedullary nailing (ESIN).

Conclusion The results of this study suggest that conventional X-ray diagnostics may not always detect comminuted clavicle shaft fractures. The treating physician should be aware of this issue.

Keywords X-ray diagnostics · Clavicle fracture · Preoperative X-ray

Introduction

For the radiological depiction and accurate classification of central clavicle fractures, obtaining X-ray images in two planes is typically recommended: an anteroposterior projection with the adjacent joints and an additional image with a 45° tilted tube [1–4]. Clavicle fractures are considered displaced if the two main fragments do not have cortical contact in at least one plane in the conventional X-ray images [5, 6]. Recent studies have suggested that patients with displaced midshaft clavicle fractures may experience a higher rate of non-union, malalignment, and functional limitations following nonoperative treatment [5, 7–9]. Conversely, better outcomes in terms of patient satisfaction, radiological results, and shoulder function have been observed after surgical treatment [10–12].

In the author's department, it has been occasionally observed that intraoperatively, more comminuted central clavicle fractures were encountered than preoperatively classified as simple fractures. Therefore, the hypothesis was formulated that not all relevant information for treatment decisions can be identified in preoperative conventional X-ray images.

In a literature review on PubMed conducted in this study, only one publication [13] was found addressing the question of recognizing complex fracture patterns, specifically

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focusing on the recognition of comminuted clavicle fractures in conventional X-ray images. The study by Jones [13] revealed that the intra- and inter-observer reliability in identifying a comminuted fracture pattern, with a Cohen's kappa of < 0.8, was only moderate.

The study presented here aims to examine whether a comminuted clavicle fracture can be reliably identified in preoperative X-ray images.

Materials and methods

For data collection, all patients treated for a central clavicle fracture at the author's department between January 1, 2012, and June 30, 2023, were identified. Data were extracted from the clinical documentation system's digital database (Orbis, Dedalus) based on ICD-10 code S42.02 for central clavicle fractures.

Inclusion criteria comprised all patients with central clavicle fractures treated surgically. Exclusion criteria encompassed fracture locations medial or lateral the central 3/5 of the clavicle, surgeries due to clavicle non-union, refracture, implant breakage, implant removal, or pathological clavicle fractures. Patients treated nonoperatively were also excluded because a comparison between preoperative X-ray morphology and intraoperative findings was not possible. Patients were further excluded if complete imaging or chart documentation was lacking.

A total of 478 patients met the inclusion criteria described above. After applying the exclusion criteria, 326 patients with complete clinical and radiological documentation remained (Fig. 1).

Age and gender distribution, fracture localization

The mean age of the study cohort was 37.5 ± 17 years (median 36.5), with the youngest patient being 15 years old and the oldest 95 years. Among the 326 patients, 73 were female, and 253 were male. The mean age on the day of surgery was 43 years for females and 38 years for males. In 174 cases, the left side was affected, and in 152 cases, the right side. No patients experienced bilateral fractures.

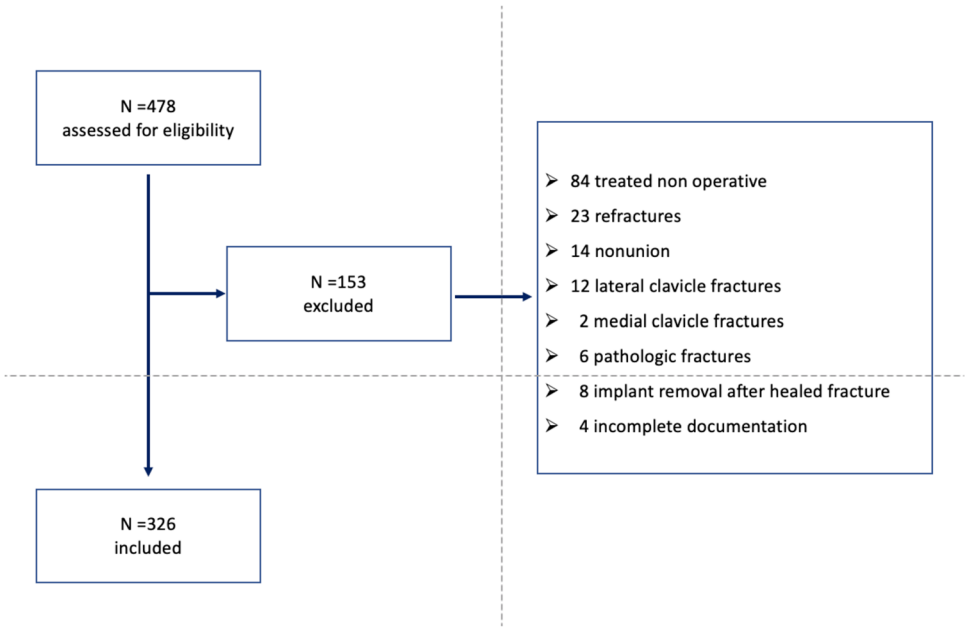
Radiographic evaluation

For diagnosis confirmation and fracture assessment, standardized clavicle X-ray images in two planes were obtained for each patient, both preoperatively and postoperatively [14]. These images consisted of an anteroposterior (AP) view and a 45° oblique view in a caudo-cranial direction [15]. Preoperative X-ray images of patients were retrospectively retrieved from the digital X-ray archive for this study.

Two specialized trauma surgeons, the primary surgeons for clavicle fractures at the clinic, initially analyzed the preoperative X-rays to determine whether a simple or a comminuted fracture was present, in order to then differentiate the fractures according to the AO classification [16, 17].

The AO classification distinguishes fractures in the location 15.2 into type A fractures, which are simple fractures consisting of two fragments; type B fractures with an additional fragment, where the main fragments can still support each other; and type C fractures, which are complex fractures, meaning there is a comminuted zone between the main fragments.

Fig. 1 Inclusion criteria



In this study, all fractures of AO type B and type C were classified as comminuted fractures.

In a second step, the surgical reports archived in the clinical documentation system were analyzed to determine whether intraoperatively a simple or comminuted fracture, or a change in the procedure, was documented.

Statistical analysis

The data presented was extracted from the digital database (Orbis, Dedalus company), patient records, and X-ray films from the archive. This data was anonymized and analyzed using the spreadsheet program MS Excel and the statistical software IBM SPSS Version 29. Prevalence, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of clavicle fracture morphology and classification based on plane X-rays were calculated using cross-tabulations (Table 1) [18].

Inter- and intra-observer reliability (Cohen's kappa) [19, 20]

Preoperative X-ray images were evaluated by two specialist physicians in Specialized Trauma Surgery. To assess inter- and intra-observer reliability, the so-called kappa coefficient (κ) was calculated.

Results

Simple/comminuted fracture patterns

On preoperative X-ray images, 109 (33%) simple and 217 (67%) multi-fragment fractures were described. In the evaluated operation reports, 78 (24%) simple and 248 (76%) comminuted fractures were identified.

The prevalence of simple fractures in conventional X-ray images is 24%, with a sensitivity of 100% and specificity of 88%. There is a positive predictive value of 72% and a negative predictive value of 100%. The accuracy is 90%.

Table 1 Cross-table

Parameter		Operation report		Sum
		Positive	Negative	
Preoperative X-ray	Positive	**a** (true positive)	**b** (false positive)	**a + b**
	Negative	**c** (false negative)	**d** (true negative)	**c + d**
Sum		**a + c**	**b + d**	**Total cases**

Table 2 presents the results regarding the detection of a multi-fragment clavicle fracture on conventional X-rays: The table shows that in the patient sample under investigation, 31 out of 248 multi-fragment fractures were only discovered intraoperatively, accounting for 13%.

The prevalence of multi-fragment fractures in the examined cohort is 76%. For preoperative X-ray diagnostics of multi-fragment clavicle shaft fractures, the sensitivity is 88%, and the specificity is 100%. There is a positive predictive value of 100% and a negative predictive value of 72%. The accuracy is 90%.

AO classification on preoperative X-ray images (Fig. 2)

One hundred nine out of 326 fractures were classified as type A (33%), 51 as type B (16%), and 166 as type C (51%) according to the AO classification. In the operation reports, 78 cases out of the 326 examined patients were classified as type A (24%), 45 as type B (14%), and 203 as type C (62%).

Figure 2 compares preoperative and postoperative results of the classification of clavicle fractures, indicating that more type C fractures were identified intraoperatively than preoperatively.

Table 2 Cross-table — comminuted fracture

Comminuted fracture		Operation report		Sum
		Yes	No	
Preoperative X-ray	Yes	217	0	217
	No	31	78	109
Sum		248	78	326

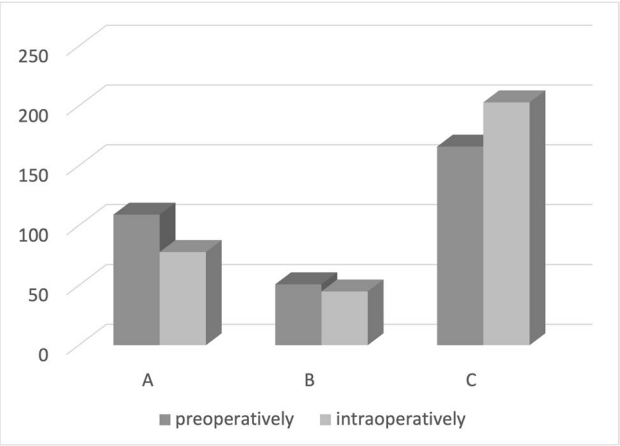


Fig. 2 Preoperative and postoperative results of the classification of clavicle fractures

Table 3 summarizes the preoperative and postoperative assessment of fracture morphology in relation to the AO classification.

It is revealed that in 43 out of 326 (13%) fractures, a discrepancy between the classification based on preoperative X-rays and the operation reports was observed. For 6 and 25 fractures that were classified as type A preoperatively, they were type B or C intraoperatively. For 12 fractures classified as type B preoperatively, they were type C intraoperatively.

Influence of classification on the operative procedure (Fig. 3)

Overall, 266 patients (82%) in the study cohort were surgically stabilized with angular stable plates, and 60 patients (18%) with elastic stable intramedullary nailing (ESIN).

Figure 3 presents the frequency of implant usage in the examining clinic for the different fracture types according to the AO classification as stacked bars. For 286 patients (88%) in the total cohort, the preoperatively planned implant was used. For 40 patients, the discrepancy between the preoperative X-ray and the intraoperative fracture type led to a change in the surgical procedure. This represents 12% of the total cohort or 93% of the fractures that were classified differently preoperatively compared to intraoperatively. In these cases (Fig. 3), fractures classified as type A ($n=31$) or type B ($n=9$) preoperatively were treated with open reduction and angular stable plate intraoperatively instead of the preoperatively planned elastic stable intramedullary nailing (ESIN).

In Fig. 3, it is clear that a total of 60 patients were treated with elastic stable intramedullary nailing. In 39 cases, fractures have been treated with closed reduction, in 21 cases needed an open reduction.

In Fig. 4, it can be seen in how many cases the preoperatively planned surgical procedure had to be carried out or altered for each fracture type according to the AO classification.

Inter-observer reliability to determine inter-observer reliability

A Cohen's kappa coefficient of 0.884 was calculated as a measure of agreement for the recognition of multi-fragment central clavicle fractures on plane X-ray images by the two observers.

Table 3 Summary

AO classification		Operation report			Sum
		AO type A	AO type B	AO type C	
Preoperative X-ray	AO type A	78	6	25	109
	AO type B	0	39	12	51
	AO type C	0	0	166	31
Sum		78	45	203	326

Discussion

The aim of this study was to evaluate the reliability of preoperative conventional X-ray diagnostics in determining whether a multifragmentary clavicular fracture was present, with the intraoperative findings serving as the gold standard. Preoperative X-rays of 326 consecutive patients with isolated central clavicular fractures who underwent surgical

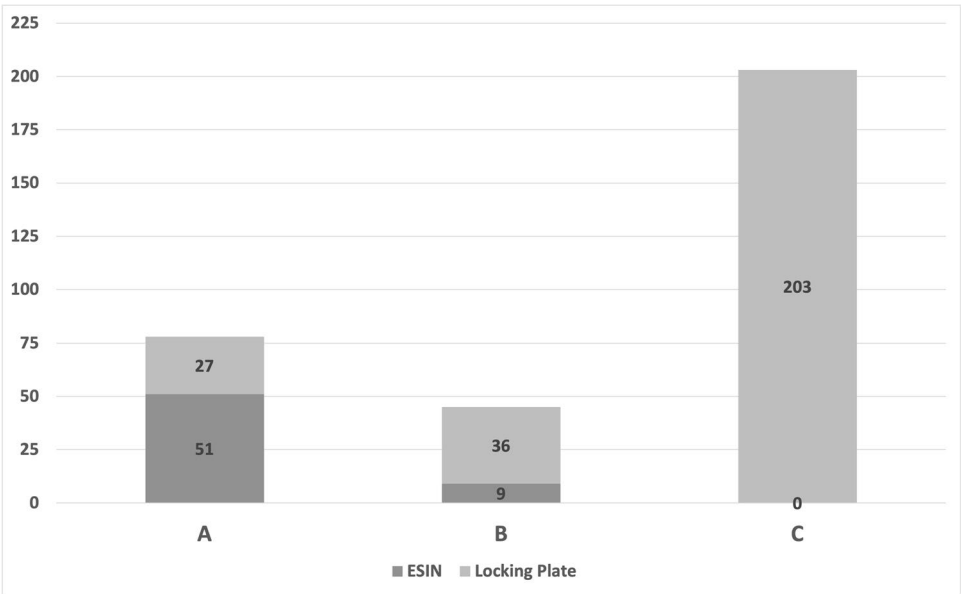


Fig. 3 Fractures' classification

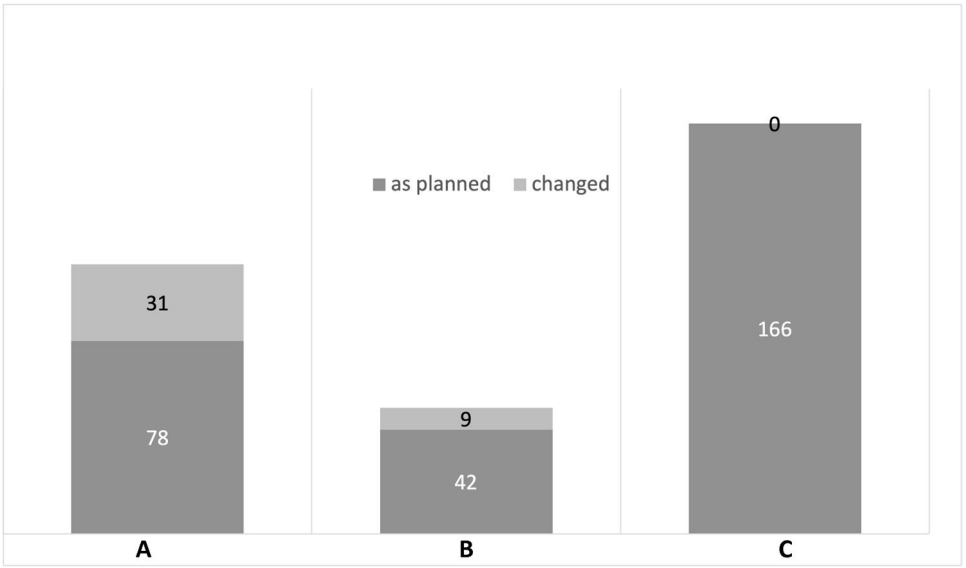


Fig. 4 Cases the preoperatively planned surgical procedure had to be carried out or altered for each fracture type according to the AO classification

treatment between July 1, 2012, and June 30, 2023, at the author's department were retrospectively compared to intraoperative findings. All fractures were classified using the AO classification system [16, 17], both pre- and intraoperatively. Surgical treatment was indicated when the extent of displacement in either of the two standard X-ray images was ≥ 100%, meaning that the main fragments in one of the standing X-ray images lacked cortical contact. Several studies have shown that standing X-rays more clearly depict the extent of displacement in central clavicular fractures compared to X-rays in supine position. At the author's department the hospital protocol stipulates that clavicular fracture X-rays be repeated in the standing position when no dislocation is evident in the supine images [14, 15].

The Nowak [21] research group found that the extent of displacement and the presence of multifragmentary fracture patterns predict poor outcomes of nonoperative treatment for adult clavicular fractures better than initial X-ray shortening measurements. Therefore, conventional X-ray imaging in two planes has a significant influence on the choice of treatment for central clavicular fractures [1, 3, 4, 22].

In the study presented here, 43 out of 326 fractures (13%) exhibited a discrepancy between preoperative and intraoperative assessments of fracture morphology. This resulted in a change in the surgical approach for 40 patients, or 93% of the discrepancy group and 12% of the entire cohort. Patients affected by a change in the surgical approach were those who, based on preoperative X-ray diagnostics, were classified as having simple type A (Fig. 4) or type B fractures according to the AO classification.

In Fig. 5, the X-ray images of a patient are shown who sustains a central clavicle fracture in a bicycle accident. The fracture was preoperatively assessed as a simple fracture, and an intramedullary procedure was planned. Intraoperatively, a ventral butterfly fragment was identified and fixed with individual lag screws. The fracture zone was bridged with a locking plate.

In the studied patient cohort, the prevalence of multifragmentary fractures was 76%, slightly higher than in other epidemiological studies [23–26]. This is likely due to the specific focus on operatively treated fractures, excluding nonoperatively managed, non-displaced fractures. This exclusion was necessary as a comparison with intraoperative findings was not possible for these fractures.

In the patient cohort analyzed here, 31 out of 248 patients (12.5%) with comminuted fractures were initially classified as having simple fractures based on conventional X-rays. This finding aligns with the results of Jones' group [13], who reported only moderate agreement between two observers regarding the assessment of conventional X-rays for the presence of multifragmentary fractures. In the study presented here, there was significantly better agreement between the two observers. In contrast to Jones' study, exclusively displaced fractures were analyzed here. Detecting comminuted clavicle fractures is easier in cases of complete dislocation, leading to better agreement between observers.

The sensitivity of conventional X-ray diagnostics for identifying multifragmentary clavicular fractures in the analyzed cohort was 88%. This implies that preoperative conventional X-rays may not always reliably detect comminuted clavicle fractures. This issue primarily affects fractures that were preoperatively categorized as AO type A fractures and, to some extent, clavicle shaft fractures assessed as AO type B before surgery [27].

The specificity of conventional X-rays for identifying multifragmentary fractures was very high at 100%. This means that when a multifragmentary fracture was identified

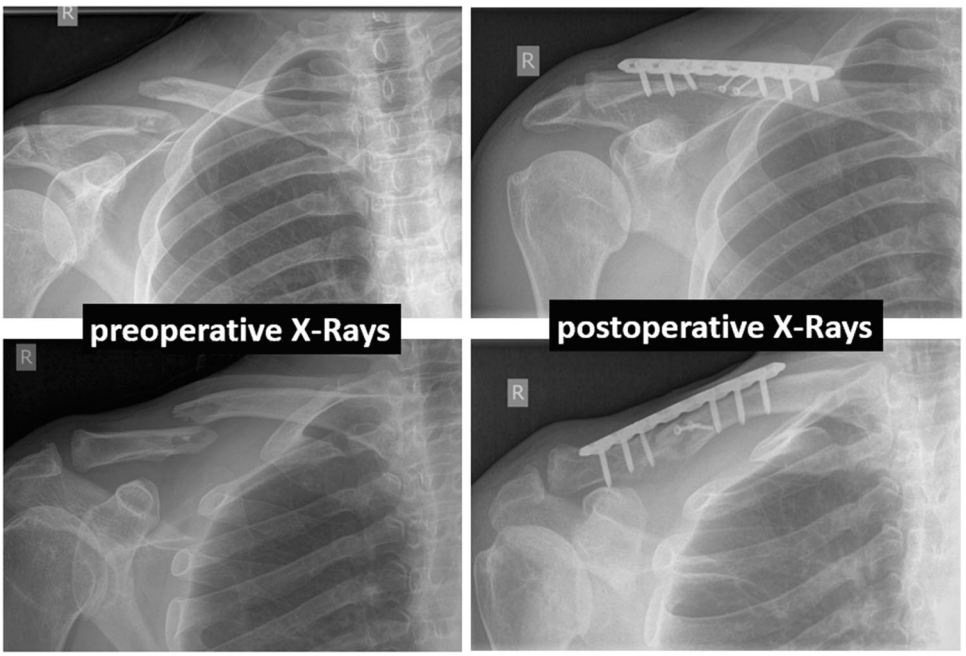


Fig. 5 X-ray images of a patient

in preoperative X-rays, it was confirmed intraoperatively in all cases.

Regarding the AO classification of fractures, we found that the sensitivity of conventional X-rays significantly decreased for higher-level fracture types. While sensitivity for detecting type A fractures was 100%, it dropped to 87% for type B fractures and further to 82% for type C fractures. This is significant because type C fractures, with a prevalence of 76% in the analyzed cohort, were the most commonly observed.

In terms of changing the surgical approach, the lower accuracy in type C fractures did not affect the outcome because in this patient cohort, angular stable plating was planned for these fracture types even before surgery. However, for AO type B fractures, elastic stable intramedullary nailing is possible if the main fragments can support each other well. In these cases, an additional incision may be necessary to achieve reduction [27].

Twelve patients who intraoperatively presented with type C fractures instead of the expected type B fractures were managed with angular stable plating instead of ESIN.

No patients initially classified with type B or type C fractures based on preoperative X-rays were found to have type A fractures intraoperatively. Therefore, preoperative conventional X-ray diagnostics exhibited a very high specificity for these fracture types, with 96% for type B and 100% for type C.

Given the challenges in detecting multifragmentary clavicular fractures with conventional X-ray diagnostics, the question arises whether routine preoperative computed tomography (CT) could aid in identifying the fracture pattern. However, it is worth considering that this imaging technique involves significantly higher radiation exposure [28]. Radiation-sensitive tissues, such as the eye lenses or thyroid gland, are exposed to ionizing radiation during CT scans due to their anatomical proximity to the clavicle. Consequently, CT scans, which are considered the gold standard for assessing fracture morphology in other body regions, are not recommended as routine diagnostics for clavicle shaft fractures. CT scans are reserved for advanced imaging of neurovascular-, thoracic-, or cervical-associated injuries, as well as polytrauma diagnostics [2]. A study by Wright and colleagues [29] compared the extent of clavicular fracture dislocation between conventional X-rays and CT scans in a small patient cohort. CT scans were available for these 26 patients as part of primary polytrauma diagnostics following high-velocity trauma. It was found that the extent of dislocation in the CT scans was 19% greater than in the anteroposterior view and 11% greater than in the 20° caudal tilted view of the clavicle [29]. The authors concluded that relying solely on standard two-plane X-ray images can lead to an underestimation of dislocation.

Conclusions

For preoperative X-ray diagnostics of comminuted clavicle shaft fractures, the sensitivity is 88%, and the specificity is 100%. There is a positive predictive value of 100% and a negative predictive value of 72%. The accuracy is 90%.

Author contributions All authors contributed to this work.

Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

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