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Review

Point-of-care ultrasound for the diagnosis of shoulder dislocation: A systematic review and meta-analysis

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ABSTRACT

Introduction: Shoulder dislocations are a common injury causing patients to present to the emergency department. Point-of-care ultrasound (POCUS) has the potential to reduce time, radiation exposure, and healthcare costs among patients presenting with shoulder dislocations. We performed this systematic review and meta-analysis to determine the diagnostic accuracy of ultrasound compared with plain radiography in the assessment of shoulder dislocations.

Methods: PubMed, Scopus, CINAHL, LILACS, the Cochrane databases, Google Scholar, and bibliographies of selected articles were assessed for all prospective and randomized control trials evaluating the accuracy of POCUS for identifying shoulder dislocation. Data were dual extracted into a predefined worksheet and quality analysis was performed with the QUADAS-2 tool. Data were summarized and a meta-analysis was performed with subgroup analyses by technique. Diagnostic accuracy of identifying associated fractures was assessed as a secondary outcome.

Results: Seven studies met our inclusion criteria, comprising 739 assessments with 306 dislocations. Overall, POCUS was 99.1% (95% CI 84.9% to 100%) sensitive and 99.9% (95% CI 88.9% to 100%) specific for the diagnosis of shoulder dislocation with a LR+ of 796.2 (95% CI 8.0 to 79,086.0) and a LR− of 0.01 (95% CI 0 to 0.17). There was no statistically significant difference between techniques. POCUS was also 97.9% (95% CI 10.5% to 100%) sensitive and 99.8% (95% CI 28.0% to 100%) specific for the diagnosis of associated fractures.

Conclusions: POCUS is highly sensitive and specific for the identification of shoulder dislocations and reductions, as well as associated fractures. POCUS may be considered as an alternate diagnostic method for the management of shoulder dislocations.

1. Introduction

Acute shoulder dislocations are a common injury, affecting between 15 and 40 patients per 100,000 person-years [1-3]. These injuries have been estimated to affect nearly 2% of the population, leading to over 200,000 Emergency Department (ED) visits each year [4,5].

Traditionally, shoulder dislocations are reduced in the ED with radiographs obtained initially to identify the dislocation and afterward to confirm the reduction. However, these routine radiographs expose patients to radiation and can result in significant time delays, as well as increased healthcare costs. Moreover, radiographs may miss some posterior dislocations and usually require transfer to a radiology suite for adequate films, which means that some patients may require re-sedation for a repeat reduction attempt if the initial attempt is unsuccessful [5].

Consequently, there has been increasing interest in the use of point-of-care shoulder sonography to identify dislocations and reductions rapidly at the bedside [6-8]. Point-of-care ultrasound (POCUS) is non-invasive, inexpensive, readily available in most EDs, and can be performed while a patient remains sedated after a reduction attempt. While early literature suggested that POCUS may be beneficial for dislocations, a number of recent large studies have been published prompting the need for this review [9-16].

The primary objective of this study is to determine the diagnostic accuracy of POCUS for identifying shoulder dislocation and reduction when compared with a gold standard of x-rays. An *a priori* subgroup analysis was planned based upon the ultrasound technique. The secondary objective was to determine the diagnostic accuracy of POCUS for identifying fractures associated with the dislocation.

2. Methods

Our study conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses - Diagnostic Test Accuracy (PRISMA-DTA) guidelines for systematic reviews and was performed in accordance

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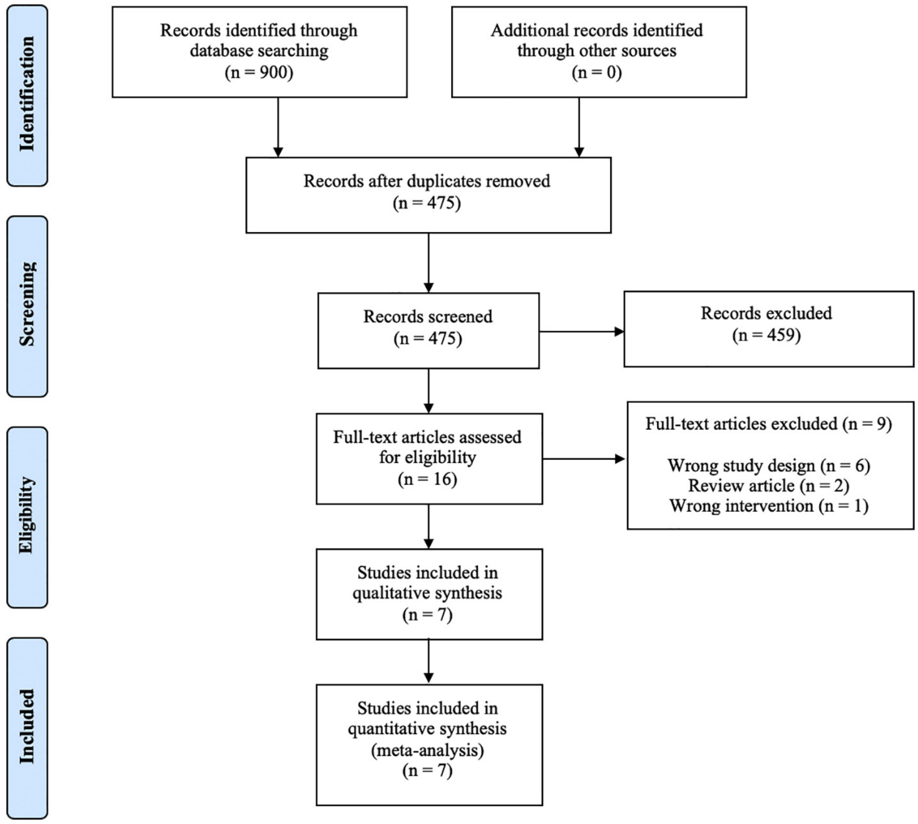

Fig. 1. PRISMA flow diagram.

with best practice guidelines [17]. This review was registered with PROSPERO (CRD42019118887). In conjunction with a medical librarian, we conducted a search of PubMed, the Cumulative Index of Nursing and Allied Health (CINAHL), the Latin American and Caribbean Health Sciences Literature database (LILACS), Scopus, Google Scholar, the Cochrane Database of Systematic Reviews, and the Cochrane Central Register of Controlled Trials to include citations from inception to January 4th, 2019. The authors also hand-searched the conference abstracts for the annual scientific meetings of the American College of Emergency Physicians, the American Institute of Ultrasound in Medicine, and the Society for Academic Emergency Medicine. Details of the search strategy are included in the Appendix. We reviewed the bibliographies of identified studies and review articles for potential missed articles. We also consulted with topic experts to help identify any further relevant studies.

2.1. Inclusion and exclusion criteria

Inclusion criteria consisted of all prospective or randomized control trials assessing ultrasound for the identification of shoulder dislocation. There were no language, date, or age restrictions. All studies must have had a confirmatory test (e.g., radiograph or computed tomogram). We excluded case reports, retrospective studies, and cadaver studies.

Two investigators independently assessed studies for eligibility based upon the above criteria. All abstracts meeting initial criteria were reviewed as full manuscripts. Studies determined to meet the eligibility criteria on full text review by both extractors were included in the final data analysis. Any discrepancies were resolved by consensus.

2.2. Data collection and processing

Two investigators independently extracted data from the included studies. The investigators underwent initial training and extracted data into a pre-designed data collection form. The following information was abstracted: last name of the first author, publication year, study country, study population size, type of study (e.g., prospective or randomized controlled trial), study location (e.g., ED, Intensive Care Unit), study inclusion criteria, study exclusion criteria, mean age of study patients, gender of study patients, percentage of shoulder dislocations, percentage of each dislocation type (i.e., anterior, posterior, inferior), ultrasound transducer, ultrasound technique, sonographer training, operator specialty, operator experience (i.e., attending or non-attending

Table 1
Characteristics of the included studies.

Study	Study population	Country	Study location	Mean patient age	Male patients (%)	Shoulder dislocations (%)	Ultrasound transducer	Ultrasound technique	Operator experience
Bianchi 1994	10	United States	ND	35.5 years	ND	2 (20%)	Linear	Posterior	ND
Abbasi 2013	142	Iran	ED	31.6 years	126 (91.3%)	71 (50%)	Linear	Anterior + lateral	Attending, resident
Ahmadi 2016	108	Iran	ED	30.1 years	91 (64.1%)	13 (12%)	Linear	Anterior + lateral	Attending
Akyol 2016	197	Turkey	ED	33.9 years	164 (80.6%)	99 (50%)	Linear	Posterior	Attending
Lahham 2016	84	United States	ED	45 years	52 (62%)	19 (22.6%)	Linear	Posterior	Student
Seyedhosseini 2017	163	Iran	ED	35.9 years	140 (83.3%)	79 (48.5%)	Curvilinear	Posterior	Attending, resident
Secko 2018	35	United States	ED	ND	ND	23 (66%)	Linear or curvilinear	Posterior	Attending

ND, not described; ED, emergency department.

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Bianchi 1994	2	0	0	8	1.00 [0.16, 1.00]	1.00 [0.63, 1.00]
Abbasi 2013	71	0	0	71	1.00 [0.95, 1.00]	1.00 [0.95, 1.00]
Ahmadi 2016	7	0	6	95	0.54 [0.25, 0.81]	1.00 [0.96, 1.00]
Akyol 2016	98	0	1	98	0.99 [0.95, 1.00]	1.00 [0.96, 1.00]
Lahham 2016	19	0	0	64	1.00 [0.82, 1.00]	1.00 [0.94, 1.00]
Seyedhosseini 2017	79	2	0	82	1.00 [0.95, 1.00]	0.98 [0.92, 1.00]
Secko 2018	21	0	2	12	0.91 [0.72, 0.99]	1.00 [0.74, 1.00]

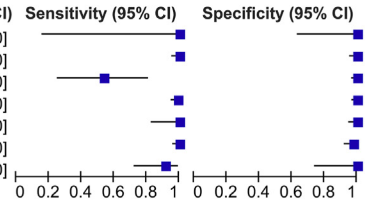

Fig. 2. Forest diagram of the overall sensitivity and specificity of ultrasound for identifying shoulder dislocations.

physician), and true positives, false positives, true negatives, and false negatives for both identifying dislocations and identifying fractures. When studies included assessments of both dislocation and reduction confirmation, the data was combined for meta-analytic purposes. Studies were independently assessed for quality by two separate investigators utilizing the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool [18]. Any discrepancies were resolved by consensus.

2.3. Data analysis

Diagnostic test accuracy variables, including sensitivity, specificity, positive likelihood ratio (LR+), and negative likelihood ratio (LR−), were calculated using a bivariate random effects model. For subgroup analysis when fewer than four studies were included, a univariate analysis was conducted. All data were calculated with 95% confidence intervals (CIs). Heterogeneity was assessed using Chi-square and I^2 statistics. A p-value <0.1 or an I^2 >50% was considered significant for heterogeneity [19]. We constructed a summary receiver-operating characteristic (SROC) curve with observed study data and a 95% CI confidence region. A linear regression test of funnel plot asymmetry with a p-value <0.1 for the slope coefficient was considered significant for asymmetry.

Statistical analysis was completed with the MIDAS module for StataMP, version 13 (StataCorp LP, College Station, Texas) to perform analyses, including bivariate random effects analyses, SROC curve analysis, assessment of publication bias, and to construct graphs. The DIAGT module was utilized for univariate analysis. Forest plots were constructed using RevMan (The Nordic Cochrane Centre, Copenhagen, Denmark), version 5.3.

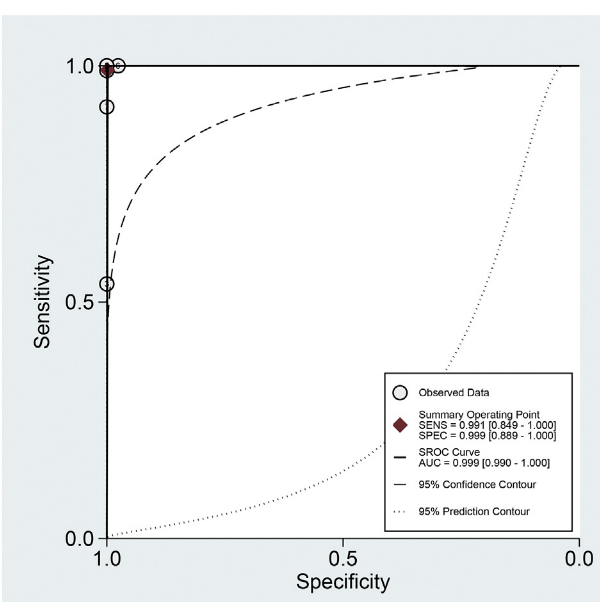

Fig. 3. Summary receiver operating characteristics of ultrasound for identifying shoulder dislocations.

3. Results

A total of 800 studies were identified. PubMed yielded 220 studies, Scopus identified 334 studies, CINAHL found 80 studies, LILACS discovered 66, the Cochrane Database of Systematic Reviews yielded no studies, and the Cochrane Central Register of Controlled Trials identified no studies. In addition, the initial 100 studies from Google Scholar were also included as recommended by Bramer and colleagues [20]. After removing duplicates, 475 original abstracts were reviewed with 16 selected for full text review (Fig. 1). No additional papers were identified by the topic experts or through bibliographic review.

Seven studies, comprising 739 total assessments, were selected for the final analysis (Table 1). All seven studies were prospective, observational trials. Three studies were conducted in Iran, [11,12,15] three were performed in the United States, [10,14,16] and one took place in Turkey [13]. Six studies took place in the ED, [11-16] while one paper did not describe the study location [10]. The majority of POCUS examinations were performed by Emergency Medicine providers [11-13,15,16]. Five studies used a linear transducer, [10-14] while one study used a curvilinear [15] and one allowed either a linear or curvilinear to be used [16]. The mean age was 35.1 years and 82.3% of patients were male. The overall dislocation rate was 41.4%. All dislocations were anteriorly displaced with the exception of two posterior dislocations.

Overall, POCUS had a 99.1% (95% CI 84.9% to 100%) sensitivity and 99.9% (95% CI 88.9% to 100%) specificity for the diagnosis of shoulder dislocation with a LR+ of 796.2 (95% CI 8.0 to 79,086.0) and a LR− of 0.01 (95% CI 0 to 0.17) (Fig. 2). The area under the SROC curve indicated high accuracy (0.999; 95% CI 0.990 to 1.000) (Fig. 3). Statistical heterogeneity was high with an I^2 of 85%. Funnel plot analysis demonstrated some evidence of publication bias (Fig. 4).

When assessing only the posterior technique, POCUS had a 99.0% (95% CI 92.3% to 99.9%) sensitivity and 99.7% (95% CI 89.5% to 100%) specificity for the diagnosis of shoulder dislocation with a LR+ of 338.7 (95% CI 8.6 to 13,395.8) and a LR− of 0.01 (95% CI 0 to 0.08)

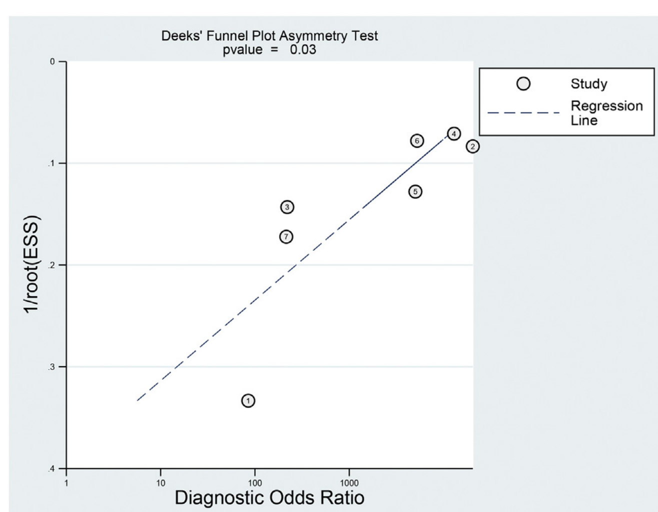

Fig. 4. Funnel plot of studies assessing the accuracy of ultrasound for identifying shoulder dislocations.

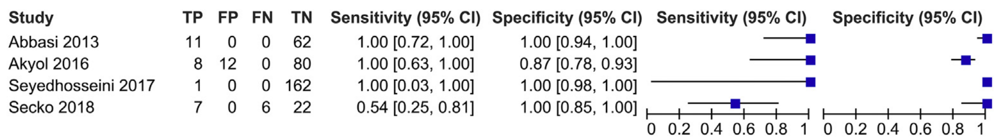

Fig. 5. Forest diagram of the overall sensitivity and specificity of ultrasound for identifying fractures.

(Supplemental Fig. 1). When assessing the anterior and lateral technique, POCUS had a 92.9% (95% CI 85.1% to 97.3%) sensitivity and 100% (95% CI 97.8% to 100%) specificity for the diagnosis of shoulder dislocation with a LR+ of 308.5 (95% CI 19.4 to 4914.4) and a LR− of 0.08 (95% CI 0.04 to 0.16) (Supplemental Fig. 2).

When assessing for the presence of an associated fracture, POCUS had a 97.9% (95% CI 10.5% to 100%) sensitivity and 99.8% (95% CI 28.0% to 100%) specificity with a LR+ of 399.2 (95% CI 0.4 to 400,138.9) and a LR− of 0.02 (95% CI 0 to 7.37) (Fig. 5). Statistical heterogeneity was high with an I^2 of 80%.

Studies were at overall low risk of bias and applicability concerns for most parameters (Table 2). Six studies were at unclear risk of bias for patient selection due to the use of a convenience sample [10-14,16]. Two studies [10,13] were at unclear risk of bias for the index test and three studies [10,13,15] were at unclear risk of bias for the reference standard due to inadequate description of the blinding technique. One study was at unclear risk of applicability for patient selection due to exclusion of posterior dislocations and patients with a body-mass index of >35 [12]. One study was at unclear risk of applicability for the reference standard due to the use of a single-view radiograph for confirming reductions [12]. No studies were at high risk for bias or applicability.

4. Limitations

It is important to consider several limitations with respect to this systematic review and meta-analysis. First, all studies were prospective, observational trials. There were no randomized control trials that were identified in this review. Therefore, it is possible there may be some unidentified confounders within the included studies. However, we did not identify any significant confounders in our review and the consistency of results suggests this is less likely. Nevertheless, future studies should consider assessing this modality with randomized control trials. Additionally, providers were not blinded to the physical examination findings, which may have influenced their decisions. However, because POCUS will be performed on patients at the bedside, we believe this is acceptable as it replicates how this would be applied in real-world conditions. Moreover, most dislocations were anterior in nature with only two posterior dislocations. While both posterior dislocations were correctly identified, more data are needed to determine the diagnostic accuracy in this important population. There was also significant statistical heterogeneity, which may have been due to variations in the training and experience level of the sonographers. While it was not possible to perform a subgroup analysis on this with the available data, we did not identify a significant difference between the diagnostic accuracy of the studies to suggest a significant influence of either factor. Future studies are needed to determine the ideal training protocol and requisite experience for this modality. Finally, it is possible that we may have missed some potentially relevant articles for inclusion. However, we performed an extensive search strategy with the assistance of a medical librarian experienced in systematic reviews, as well as searches of bibliographies and discussion with content experts, so we believe the risk of this is minimal.

5. Discussion

Our systematic review and meta-analysis demonstrates that POCUS is highly sensitive and specific for identifying shoulder dislocation and reductions. Additionally, no significant difference was identified when comparing the assessment techniques.

This data has significant patient and provider implications with respect to time, cost, and radiation. One study found that pre-reduction radiographs alone delayed the time to treatment by 30 minutes [21]. This has the potential to worsen muscular spasm, resulting in a more difficult reduction, as well as increase the overall patient length of stay. POCUS could be performed rapidly at the bedside to diagnose the shoulder dislocation, as well as confirm proper relocation after the reduction attempt. In the latter case, this would avoid the need to resedate the patient after the attempt if it was not successfully relocated (by identifying the need for a repeat attempt while the patient remains under the initial sedation). Additionally, POCUS may decrease overall healthcare costs by reducing the total number of radiographs performed, especially given the high incidence and prevalence of this condition [1-5].

Interestingly, POCUS was also sensitive and specific for identifying associated fractures. Unfortunately, the confidence intervals were relatively wide and further studies are needed to better determine the diagnostic accuracy and clinical utility of POCUS for this modality [21-23].

Two previous systematic review were performed in this topic in 2015 and 2017 [9,24]. The most recent systematic review by Gottlieb and Russell identified four studies comprising 531 total assessments and suggested that POCUS may be a considered as a potential modality for identifying shoulder dislocations but suggested that more studies were needed [24]. Our current review performed a more expanded search and was conducted two years after the most recent review, identifying three additional studies and increasing the total assessments by 30%. Additionally, this the first review to perform a meta-analysis, as well as a subgroup analysis by the assessment technique. Finally, this is the first systematic review to also assess the diagnostic accuracy of POCUS for identifying associated fractures.

Table 2
QUADAS-2 for included studies.

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Bianchi 1994	U	U	U	L	L	L	L
Abbasi 2013	U	L	L	L	L	L	L
Ahmadi 2016	U	L	L	L	U	L	U
Akyol 2016	U	U	U	L	L	L	L
Lahham 2016	U	L	L	L	L	L	L
Seyedhosseini 2017	L	L	U	L	L	L	L
Secko 2018	U	L	L	L	L	L	L

L, low risk of bias; U, unclear risk of bias.

As with all ultrasound applications, there can be operator variability. While the consistently high accuracy with a range of sonographers in this review suggests a broader applicability of this skill, future studies should determine the ideal training protocol for shoulder sonography. Additionally, future studies should compare the two primary POCUS techniques to determine which technique is the most accurate.

6. Conclusion

POCUS is highly sensitive and specific for the identification of shoulder dislocations and has the potential to decrease time, healthcare costs, and radiation exposure. POCUS may be considered as an alternate diagnostic method for the management of shoulder dislocations.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2019.02.024.

Disclosures/funding

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Meetings

None.

IRB

N/A.

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Appendix A. Search strategy

PubMed: 220

("Shoulder Dislocation"[Mesh] or "Shoulder dislocation" or "Shoulder dislocations" or "shoulder relocation" or "shoulder reduction" or "shoulder reductions" or "dislocation of the shoulder" or "dislocated shoulder" or "dislocated shoulders" or "shoulder instability" or "shoulder subluxation")

AND ("Ultrasonics"[Mesh] OR "Ultrasonography"[Mesh] OR ultraso* OR sonogra* or POCUS)

Scopus: 334

(TITLE-ABS-KEY(({Shoulder dislocation} or {Shoulder dislocations} or {shoulder relocation} or {shoulder reduction} or {shoulder reductions} or {dislocation of the shoulder} or {dislocated shoulder} or {dislocated shoulders} or {shoulder instability} or {shoulder subluxation}))

AND (TITLE-ABS-KEY(ultraso* OR sonogra* or POCUS))

CINAHL: 80

Cochrane Central Register of Controlled Clinical Trials: 16

Cochrane Database of Systematic Reviews: 0

((MH "Shoulder Dislocation") OR ("Shoulder dislocation" or "Shoulder dislocations" or "shoulder relocation" or "shoulder reduction" or "shoulder reductions" or "dislocation of the shoulder" or "dislocated shoulder" or "dislocated shoulders" or "shoulder instability" or "shoulder subluxation"))

AND ((MH "Ultrasonography") OR (ultraso* OR sonogra* or POCUS))

LILACS: 66

(("shoulder dislocation" or "dislocated shoulder" or "shoulder reduction" or "shoulder relocation" or "shoulder subluxation")) AND (ultraso* OR sonogra* or POCUS)

Google Scholar: First 100

("Shoulder dislocation" OR "shoulder reduction" OR "shoulder relocation" OR "dislocation of the shoulder" OR "dislocated shoulder" OR "shoulder instability")

AND (ultrasound OR ultrasonography OR sonograph OR sonography) -guided

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