Journal of Pediatric Surgery 55 (2020) 2009–2014

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Sedated ultrasound guided saline reduction (SUR) of ileocolic intussusception: 20 year experience

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ARTICLE INFO

Article history:
Received 7 January 2020
Received in revised form 14 May 2020
Accepted 19 May 2020

Key words:
Intussusception
Ultrasound guided
Sedation
Saline enema

ABSTRACT

Background: Ileocolic intussusception is a common abdominal emergency in children, diagnosed routinely with ultrasound and treated most frequently with fluoroscopic pneumatic reduction without sedation. Alternatively, ultrasound can also be used to obviate ionizing radiation and sedation can be used to avoid discomfort from the procedure. The purpose of this study was to present our experience with sedation using saline enema under ultrasound guided control to reduce ileocolic intussusception.
Materials and methods: This is a retrospective study of patients with ileocolic intussusception presenting to a tertiary care hospital between 1998 and 2018. We excluded the data of patients that underwent either fluoroscopic guided reduction with barium enema or primary surgery. All patients received sedation with propofol and subsequently underwent our sedated ultrasound guided saline reduction (SUR) protocol until reduction was confirmed.
Results: 414 total reductions were performed in the 338 children who underwent our SUR protocol, of which 86.0% were successful. Zero perforations occurred during attempted reduction. 58 patients required surgery after a failed reduction (14.0%). There were 76 recurrent episodes that underwent our SUR protocol, of which 93.4% had a successful reduction.
Conclusion: The success rate of reduction was high and compared similarly to techniques that either use pneumatic reduction under radiation or refrain from administering a sedative prior to enema.
Level of evidence: Treatment study level III.

Intussusception is defined as a prolapse of one part of the intestine into the lumen of an immediately adjoining part. It is an entity of children, representing the most common cause of acute abdomen in infancy and is the most common abdominal emergency in children younger than two years of age [1,2]. In the majority of cases there is no obvious cause other than lymphoid hyperplasia [3]. If not properly managed it can lead to bowel necrosis and thereby necessitates prompt diagnosis and management [4,5].

The presentation of intussusception has been well described. The "classic" clinical triad of symptoms consists of: an acute colicky abdominal pain, "currant jelly" or frankly bloody stools, and either a palpable abdominal mass or vomiting. Most children do not present with the complete triad of symptoms [1,2].

Owing to its morbidity, accurate and quick diagnosis has been thoroughly investigated, and sonography is a proven diagnostic tool. Sonography is highly accurate in diagnosing intussusception, with reported sensitivity rates of 98%–100% and specificity rates of 88%–100% [2,6,7]. Furthermore, sonography can show additional pathologies that can be a leading point for the intussusception [8]. Depending on the affected bowel part, several types of intussusception can be distinguished. The most frequent treatable form is ileocolic [2], and the most common location at time of radiologic examination is at the hepatic flexure or right upper quadrant [8].

Sometimes described as a target/donut sign or pseudokidney sign, the sonographic imaging of intussusception represents the intussusceptum within the intussuscipiens with hyperechoic mesenteric fat, mesenteric vessels, and thickened intestinal walls owing to venous congestion and edema [1,2,8].

Nonoperative reduction by enema is the established first line treatment for intussusception. Even though ultrasound is a well-established modality for diagnosis, it is less widely used as a therapeutic imaging method for intussusception reduction.

Independent of the imaging modality used, the procedure is invasive and unpleasant for the child. However, usage of sedation is not

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https://doi.org/10.1016/j.jpedsurg.2020.05.049
0022-3468/

commonly practiced in these patients owing to previously published general recommendations that suggest the Valsalva maneuver in nonsedated infants and children is protective against perforation [9].

The purpose of this study is to present our twenty year institutional experience in the reduction of ileocolic intussusception using our sedated ultrasound guided saline reduction (SUR) protocol. Its success, failure, and complication rates relative to other techniques and protocols will be reviewed. Additionally, our experience with sedation prereduction will be discussed.

1. Method and materials

This is a retrospective study of patients presenting to a tertiary care hospital. Our project was approved by the institutional review board according to the Helsinki protocol. A search through the hospital's EMR identified patients who underwent SUR during the years 1998–2018.

We excluded the data of patients that proceeded straight to surgery or underwent fluoroscopic guided barium enema reduction. Those that went straight to primary surgery did so owing to the surgeon's clinical decision based on other imaging and clinical data (Table 1).

All patients diagnosed by ultrasound with intussusception in the emergency room were brought to the pediatric operating room within 6 h. Once in the operating room, an attending radiologist with knowledge of the protocol performed a repeat diagnostic ultrasound. If intussusception was still present all patients were sedated with IV propofol 2 mg/kg by an anesthesiologist. At that point, a rectal tube was placed using a 24F Foley catheter and taped to the buttocks to provide a tight seal. Repeat confirmatory ultrasound was then performed and if positive for ileocolic intussusception, saline solution was infused into the colon by gravity with a saline bag hung 1.2 m above the bed. This saline enema was performed under ultrasound supervision until filling of the cecum was visualized. The cecum was visualized by its large hollow viscus and less noticeable haustral folds at the beginning of the ascending colon, or less frequently by its ileocecal valve which appeared as a slit-like opening medial to the cecum. If reduction did not occur initially, the saline bolus was maintained for 30 s until reduction or manual suction evacuation of the saline bolus. After a one-minute break, if intussusception was still present on intraoperative ultrasound, repeat hydrostatic reduction was attempted up to four additional times in the same session.

Success was defined by ultrasound confirmed resolution of intussusception. This was further stratified into whom saline was introduced in the colon under sedation, and reduction that resolved either prior to anesthesia (RPA) or after anesthesia (RAA) without enema. Success of the procedure was confirmed by the radiologist using ultrasound to visualize both the disappearance of ileocolic intussusceptum mass and the filling of the cecum by visualizing saline passing from cecum to ileum through the ileocecal valve [10]. Data collected included patient demographics, abdominal quadrant location of intussusception, observation of free fluid, spontaneous reduction prior to or after sedation, failure rate, perforation, need for surgery, and evidence of recurrence. We analyzed the success rate of primary episode reduction based on age, gender, quadrant location, and free fluid.

Table 1
Patients who went straight to surgery owing to surgeon's preference.

		Total ($n = 26$)
Lead points		
	Meckel's diverticulum	4
	Lymphadenopathy	4
	Henoch–Schonlein purpura	4
	Edema	2
	Burkitt's lymphoma	1
	Bowel ischemia	1
Other		
	Delayed presentation	1
	Unknown	6

Patients with recurrent intussusception episodes were also recorded. Data collected included patient demographics, recurrent episodes per patient, days passed since last episode, spontaneous reduction prior to or after sedation, failure rate, perforation, and need for surgery. We analyzed the success rate of recurrent episode reduction based on age, sex, and time passed since last episode.

Failure was defined by lack of reduction, perforation during reduction, or those requiring surgical management after attempts at repeat hydrostatic enema reductions.

Rates of success, failure, perforation, and recurrence in our protocol were compared to multiple similar published results from studies using both fluoroscopy and ultrasound, sedated and nonsedated.

All statistical analyses were performed with R 3.5.3 software for variables that had clinical importance. Analyses were conducted on data from both primary and recurrent intussusception episode reductions. Quantitative values were expressed as mean and standard deviation. Qualitative values were expressed as percentages. Chi-squared test and Mann Whitney U test were used to analyze data when appropriate. A p-value less than 0.05 was considered significant.

2. Results

A summary of the study patients and various groups and subgroups is provided in Fig. 1. A total of 446 episodes of ileocolic intussusception were diagnosed during the study period. 32 patients did not undergo the SUR protocol and were excluded from the data set. This included 6 patients who underwent fluoroscopic guided barium enema and 26 who were treated by primary surgery owing to the surgeon's preference. The episodes that underwent primary surgery were either associated with various lead points (4 Meckel's diverticulum, 4 lymphadenopathy, 4 Henoch–Schonlein purpura, 2 edema, 1 Burkitt's lymphoma, 1 ischemia) or delayed presentation (Table 1). 6 cases are not recorded.

There were 414 total episodes that entered our SUR protocol, of which there were 338 primary episodes and 76 recurrent episodes (Fig. 1). Of the 338 primary episodes, 213 were seen in males and 125 were seen in females. The mean age and range of ages at the time of a primary intussusception were 11.1 and 1 to 61 months respectively. The median age at primary episode presentation was 8 months (interquartile range [IQR] = 5 to 12 months). Peritoneal free fluid was observed in 70 patients (Table 2). The primary intussusception episode was diagnosed most frequently in the RUQ (75%) (Table 3).

Of the 338 primary episodes that entered into the SUR protocol, 285 were successfully reduced (84.3%) while the 53 nonreducible cases proceeded to surgery (15.7%). Of the 285 that were successful, 8 were RPA, 20 were RAA, and 257 were reduced with saline enema (82.9%) (Fig. 1). No perforations occurred.

There were 84 total recurrent episodes, 18.8% of total episodes identified. Of these 84, 76 episodes proceeded with our SUR protocol while 8 episodes were excluded. 5 of those excluded proceeded straight to surgery and 3 underwent fluoroscopic guided barium enema reduction. Of the recurrent episodes, 57 occurred in males while 19 occurred in females. The mean age at recurrent episode presentation was 17.3 months (2–59). The median age at recurrent episode presentation was 12 months (IQR = 7 to 23 months). The mean time was 149 days (1–1380) between a previous and current episode, while the median time was 35.5 days (IQR = 1.75 to 157.5 days) (Table 2). Most patients experienced only one recurrence (82.9%) while 9.2% experienced two recurrences, 6.6% experienced three recurrences, and 1.3% experienced four recurrences.

Of the 76 recurrent episodes that proceeded to our SUR protocol, 71 were successfully reduced (93.4%). Of the 76, 64 proceeded with saline enema while 12 were RAA. In those that received saline enema, 59 were successfully reduced (92.2%). In the 5 episodes that failed to resolve under the SUR protocol (6.6%), exploratory laparoscopy was then performed in each case. 4 of the 5 were found to have obstruction caused

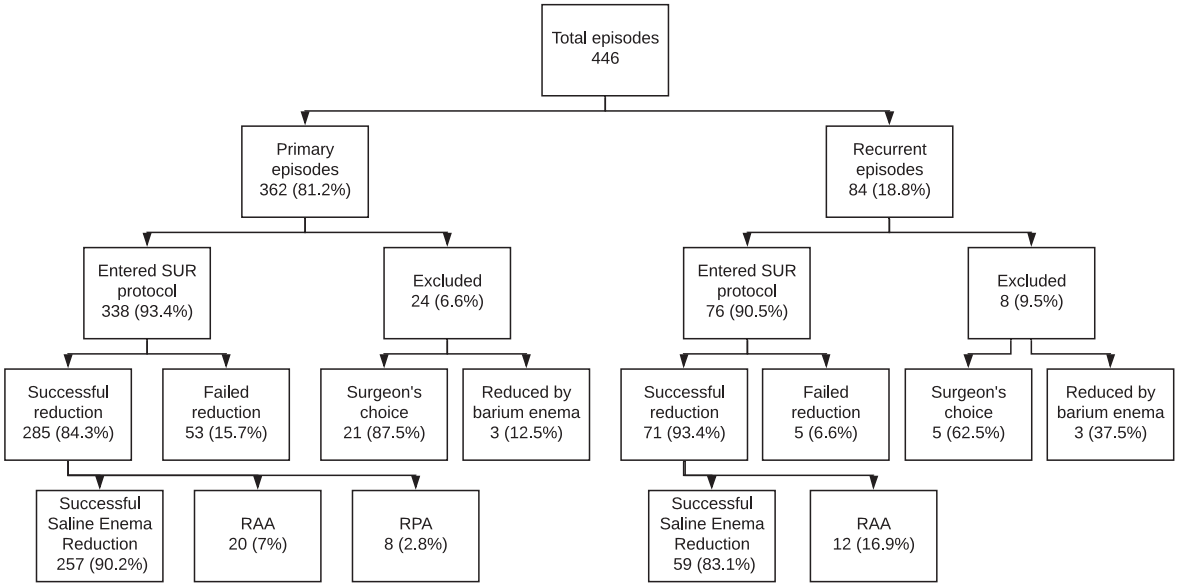

Fig. 1. Outcomes from total episodes of ileocolic intussusception in our sample. SUR: sedated ultrasound guided saline enema. RAA: resolved after anesthesia. RPA: resolved prior to anesthesia.

by lymphedema, while 1 was found to be caused by an incarcerated appendix. Only 1 failed reduction occurred after the first recurrence. 4 of the 5 failed reductions occurred within 3 months of the prior episode.

28 cases (37%) of recurrent episodes occurred within 5 days of reduction. In this group there was a 7% reduction failure compared to the 6.3% reduction failure in those that had a recurrent episode after 5 days from last reduction.

The comparative statistical analysis of primary episodes is presented in Table 4. There was no association with sex of the patient and reduction success. There were statistically significant associations of success rate with older age at first diagnosis ($P = 0.016$), absence of free fluid ($P = 1.803e\text{-}05$), and RUQ localization ($P = 0.0048$).

The comparative statistical analysis of recurrent episodes is presented in Table 4. There was no association with sex of the patient, age at time of recurrent episode, time passed from last episode and reduction success.

Overall, 414 total episodes underwent our SUR protocol, with 356 total successful reductions (86%). 316 of the 356 cases were successfully reduced after saline enema, for a success rate of 84.5%. 32 (9%) successful cases were attributed to spontaneous reduction of intussusception following administration of IV propofol. There were zero instances of perforation. 58 total nonreduced intussusception episodes (14.0%) proceeded to successful surgical management.

Table 2
Characteristics of patients presenting with intussusception.

	Primary episode	Recurrent episode
Sex	213 boys 125 girls	57 boys 19 girls
Median age (months) at initial presentation (IQR)	8 (7)	9 (6)
Median age (months) at recurrent presentation (IQR)	NA	12 (7–23)
Median time (days) passed since last episode (IQR)	NA	35.5 (1.75–157.5)
Free fluid	No: 256 Yes: 70 Unknown: 12	NR

IQR = interquartile range; NA = not applicable; NR = not recorded.

3. Discussion

Various techniques have been investigated over time to nonsurgically reduce intussusception. Fluoroscopic guided intussusception reduction using either hydrostatic or pneumatic enema is the most commonly used technique [1,11], with success rates ranging from 68% to 90% [12]. While fluoroscopic guided reduction studies report high success rates, the technique poses potential risks to the patient owing to the exposure to ionizing radiation [13]. Reduction of intussusception can potentially become protracted with increased radiation exposure, theorized to potentially result in a small increase in lifetime risk of cancer [2,6]. Fluoroscopic pneumatic reduction also increases the risk of tension pneumoperitoneum following perforation, a complication that necessitates emergent management [13].

The use of therapeutic sonography for reduction does not expose children to the dangers of ionizing radiation. Yet, according to a recent survey among radiologists, only 4% report using sonography as their method of choice to reduce intussusception [11]. It is most often performed with hydrostatic rather than pneumatic enema owing to the interference of air in sonographic visualization. Although ultrasound guided pneumatic enema reduction is a proven method, the intussusception resolution is only visualized once the bowel has been given time to decompress. Thus, it does not allow real-time visualization of the cecum and the ileum as the introduced air precludes proper sonographic monitoring for resolution [5,14]. Success rates range from 76% to 95% [12,15]. In contrast to the fluoroscopic image, ultrasound guided enema allows visualization of the entire ileocecal valve, which serves as a more reliable tool for confirming intussusception reduction [13]. Some of the relevant literature reported ultrasound guided hydrostatic enema

Table 3
Localization of intussusception of patients presenting with a primary episode.

Localization	Total	Success	Failure
RUQ	253	222	31
RLQ	29	24	5
LUQ	13	11	2
LLQ	9	1	8
Other	34	27	7

RUQ: right upper quadrant; RLQ: right lower quadrant; LUQ: left upper quadrant; LLQ: left lower quadrant; Other: nonspecific/unknown.

Table 4
Comparative statistical analysis: primary episodes vs. recurrent episodes.

Variables	Primary reduction success ($n = 285$)	Primary reduction failure ($n = 53$)	*P*-value	Variables	Recurrent reduction success ($n = 71$)	Recurrent reduction failure ($n = 5$)	*P*-value
Sex	176 boys (62%) 109 girls (38%)	37 boys (70%) 16 girls (30%)	NS[a]	Sex	52 boys (75%) 19 girls (25%)	5 boys (100%) 0 girls (0%)	NS[a]
Median age, [IQR] (months)	8.5 [8]	6.0 [4]	0.016[b]	Median age (months) at recurrent presentation [IQR]	12 [15]	34 [26]	NS[b]
Free fluid	47 Yes (16%) 228 No (80%)	23 Yes (43%) 28 No (53%)	1.803e-05[a]	Median time (days) passed since last episode [IQR]	45 [163.5]	6 [71]	NS[b]
RUQ localization	222 (78%)	31(58%)	0.0048[a]				

NS = nonsignificant; IQR = interquartile range.
[a] Chi-squared test.
[b] Mann Whitney U test.

to have higher complication rates and lower success rates in reduction [16–18], while others found no difference between the methods [6,9,11,12].

Sadigh et al. [12] reviewed more than 32,000 children with intussusception in a 2015 meta-analysis and reported important outcomes, including average rates of success among air (84%) versus fluid (68%) enema reduction, fluoroscopic (89%) versus ultrasound guided (86%) reduction, as well as perforation rate seen in air (0.39%) versus saline (0.43%) enema. Using saline enema in our protocol, we report comparable rates of reduction using saline enema and ultrasound (84.5%), and we report a lower perforation rate (0%) than other series reviewed in this meta-analysis.

The risk of recurrence is independent of enema type and there are high rates of success with repeat enema reduction [12,19]. We report 76 total recurrent episodes of intussusception undergoing SUR with a 92.2% successful reduction rate after enema and 6.6% failed reduction rate after enema. Both our recurrence and success rates are relatively high compared to other studies using similar technique (Table 5).

We looked at both patient and diagnostic characteristics as potential risk factors for success and failure. We found that older age at time of diagnosis, absence of free fluid, and right upper quadrant localization were significant measures of predicting successful primary reduction, results that are consistent with reports from other investigators [6,15]. Sex demonstrated no significant association as a risk factor for primary reduction (Table 4). For those presenting with a recurrent episode, we examined the effect of sex, age, and time passed since last episode as features on the outcome of reduction. We found no significant association between sex, age, or time passed since last episode and recurrent reduction outcomes (Table 4).

Intussusceptions localized to the right upper quadrant were successfully reduced in 87.7% of cases, while those localized to the left lower quadrant failed in 88.9% of cases (Table 3). Takahashi et al. [20] examined the relationship between successful hydrostatic reduction and position of the head of the intussusception. They found that the majority of successful reductions were seen closer to the right colon while 88% of failed cases were seen more distal to the right transverse colon. They suggested that because patient symptoms in the failed group were longer than in the success group, longer duration of symptoms can be associated with a greater length of intussusception bowel with a tip that is more distal. Although we did not examine the duration of symptoms in our protocol, it is likely that left-sided intussusceptions migrated through the colon over time, and may have been present longer than those still in the right side by the time of our initial ultrasound.

The young age of patients undergoing attempted reduction can lead to an increased amount of fear and restlessness, which can deter successful outcomes. The use of sedation in intussusception reduction is not standard practice as historical reports suggest the lack of increased abdominal pressure generated by an awake child removes a safeguard against perforation [9]. Because of this as well as other reasons, the use of sedation has been reported to have decreased from up to 54% to as low as 7% [11]. When sedation is used, midazolam is the most popular sedative [11]. Despite its low usage, sedation when used with both ultrasound and fluoroscopic guided reduction nevertheless displays excellent success rates (85%–92%) and low perforation rates (0.4%–1.5%) [15,21].

Our reduction rate compares favorably to other series that used fluoroscopic reduction under sedation [21,22]. Both Ilivitzki et al. [21] and Purenne et al. [22] demonstrated successful reduction and low complication rates using IV propofol as the anesthetic of choice.

Table 5
Comparison of large series of sedated US-guided reduction.

	Number of episodes attempted with enema reduction	Primary reduction success rate (%)	Recurrence rate (%)	Recurrent episode success rate (%)	Sedative	Patients sedated[a]	Number of perforations
Bai et al., 2006	5218	95.5	5.6	Unknown	Wintermin	All patients	9
Flaum et al., 2016	271	85.2	14.5	61.2	Midazolam	Selected patients	1
Digant et al., 2012	30	87	0	NA	Ketamine	All patients	0
Rohrschneider and Troger, 1995	46	91	15	80	Diazepam or chloral hydrate	All patients	0
Peh et al., 1996	25	76	Unknown	Unknown	Meperidine hydrochloride	All patients	0
Wang and Liu, 1988	377	95.5	Unknown	Unknown	Wintermin	NS	1
Chan et al., 1997	26	73	11.5	100	Pethidine	All patients	0
Sacks et al., 2020	414	84.3	19	93.4	Propofol	All patients	0

NA = not applicable; NS = not specified.
[a] If there was a standard procedure for administering sedation.

We compared our sedated protocol to other series using ultrasound guided reduction without sedation. These series all used ultrasound guided saline enema reduction in their protocol, and our overall success rate (86%) compares equally to their reported rates (83.5%–100%) [23–25].

In comparison to other series using ultrasound guided reduction under sedation [4,10,15,26–29], our total successful reduction after saline enema rate appears favorable (Table 5). Although sedation was used in these other series, notable methodological differences exist between theirs and ours. We chose to sedate all patients and each time we used the same sedative, specifically IV propofol. We reported 40 episodes of spontaneous reduction in the pediatric operating room, from the time of initial diagnostic ultrasound up to initiation of therapeutic enema: 8 RPA and 32 RAA. The 32 RAA episodes account for 9% of all successful reductions and suggest that sedation may be a treatment modality option in intussusception cases. To date, there are no studies with a larger sample size that include the detailed effect of sedation, particularly IV propofol, on intussusception reduction alone. Our zero instances of perforation after 414 total reductions also help suggest that the use of anesthesia during intussusception reduction does not necessarily lead to an increased risk of complications.

Additional advantages of ultrasound include its minimal chances for chemical peritonitis even if a perforation occurs and its quick versatility in the operating room. There is no fluctuation in the intracolonic pressure, as is seen in fluoroscopic pneumatic enema, and therefore there is less potential for tension effect in the peritoneum if perforation occurs. Furthermore, there is no incidence of a pseudoreduction as is seen in the fluoroscopic guided procedures as the real time ultrasound shows the entire process of the reduction, leaving no ambiguity [26]. Ultrasound guidance allows the procedure to be performed in the operating room, a better-controlled environment than the fluoroscopy suite allowing immediate conversion to a surgical approach if perforation occurs. In cases of an unsuccessful reduction it enables the surgical operation to be initiated quickly.

There were several limitations in the study and our protocol that should be addressed. This is a single institution nonblinded retrospective study. The patient outcomes were based solely on review of past medical records, which were neither systemically categorized nor regularly inclusive. The long time period (20 years) of data collection creates challenges in both accessing certain files that are no longer available and assessing any changes to our SUR protocol. Other useful outcome factors such as complete reduction time, presenting symptoms, length of stay in hospital, time from diagnosis to SUR, and free fluid seen with recurrent episodes, are not taken into consideration as therapeutic factors and are not recorded systematically in the electronic medical records. More standardized documentation could improve patient outcomes in the future. Additionally, our SUR procedure requires the knowledge of ultrasound techniques which is often less readily available at smaller or underresourced hospitals. The training level of the radiologist performing the procedure is a well-described indicator of successful ileocolic intussusception reduction. Crystal et al. [6] describe this significant role in predicting outcomes showing that dedicated pediatric radiologists on-call during the emergent procedure led to better reduction outcomes. Success rate for each dedicated pediatric radiology on-call personnel (93%) was significantly higher than general radiologists or radiology residents (62%) performing the same procedure. In our SUR protocol the radiologists performing the procedure were either pediatric or adult radiologists with at least ten years of experience of reducing intussusception. Our SUR protocol was not attempted with inexperienced radiologists.

4. Conclusion

In our experience, sedated ultrasound guided intussusception reduction maintains the reduction rate overall without exposing children to both harmful ionizing radiation and pain associated with hydrostatic enema. In our opinion, our success rate and lack of perforation are points which confirm the validity of ultrasound as being perfectly suited for administration of this protocol. Ultrasound allows direct, real-time visualization of the cecum, while still allowing high rates of successful reduction, and sedation decreases patient discomfort without increasing the perforation rate.

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