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Original article

Sutureless elastic ring silo for the gastroschisis

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Background: The definitive surgical management of gastroschisis is the return of the eviscerated abdominal content into the abdomen as soon as possible.
Objectives: Assess the efficacy of using a sutureless elastic ring silo (SERS) for the management of gastroschisis.
Methods: Neonates with gastroschisis were enrolled at Songklanagarind Hospital between January 2006 and December 2008. A primary repair (PR) was attempted in all cases. If this was not possible due to concerns about abdominal compartment syndrome, a stage abdominal closure with a silo pouch was fashioned: a traditional silo (TS) or SERS. When the bowel was completely reduced, a second-stage closure was performed in the operating room. Data collected included general demographic data, size of defect, associated anomalies, hospital course, mode of gastroschisis closure, duration of parenteral nutrition (PN) and ventilator, first feeding age, complications, and length of hospital stay (LOS).
Results: Twenty-nine children with gastroschisis were treated (PR: 9, TS: 9, and SERS: 11). There were no differences ($p > 0.05$) concerning gender, mode of delivery, APGAR scores, gestational age, birth weight, or defect size. A preformed silo was employed in 20 of 29 cases, TS in nine (31%), and SERS in 11 (38%) cases in an average operative time of 80.6 and 40 minutes, respectively, a significantly shorter operative time in the SERS ($p = 0.007$). Overall, there were no differences ($p > 0.05$) concerning duration of ventilator support (10.2 days), duration of PN (21.3 days), first feeding age (15 days), LOS (26.5 days), and complication.
Conclusion: The use of a sutureless elastic ring silo with readily available inexpensive materials is simple, safe and efficacious in our setting.

Keywords: Abdominal wall defects, gastroschisis, preformed silo, staged closure, sutureless silo, umbilical cord preservation

Gastroschisis is an abdominal wall defect with eviscerated abdominal content. Usually, the defect is less than 4 cm in width and located immediately to the right of the umbilicus. The incidence rate is about 2 to 4.9 per 10,000 live births, with a male preponderance [1, 2].

Immediate care focuses on protecting the eviscerated bowel, preventing hypothermia, and providing appropriate fluid resuscitation. Inappropriate or careless coverage and positioning of the eviscerated bowel may cause vascular compromise and bowel ischemia. Visceral care can involve the spring loaded silo (SLS), transparent Silastic silo, body bag, or wrapping of the exposed intestine. The infant should be transported in the lateral position with bowel content supported, and the intestine should not kink at the fascial level. This protects against interrupting the blood supply of the extraperitoneal intestine. However, for patients treated with the SLS, the patient could be placed in the more comfortable supine position with only some supports for hanging the silo at the top of the container.

Current definitive surgical management of gastroschisis returns the eviscerated abdominal content into the abdomen as soon as possible through primary abdominal fascia and skin closure. If primary closure is impossible due to viscero-abdominal

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disproportion or increased abdominal hypertension, an artificial pouch or silo is placed with subsequent serial reduction [3], and later followed by definitive closure. The spring-loaded silo with no sutures is used for gastroschisis reduction in most Western settings [4-7]. However, it is not performed in Thailand where the current procedure is an in-house prepared silo sutured directly to the fascia or the skin at the defect's rim.

This study aimed to assess the efficacy of employing a SERS for the management of gastroschisis, when there were readily available inexpensive materials.

Materials and methods

Neonates with gastroschisis treated at Songklanagarind Hospital between January 2006 and December 2008. A primary repair (PR) was attempted in all cases. This study was approved by Songklanagarind Hospital's Research Ethics Committee.

Surgical technique

Unless there had been a prenatal diagnosis, after delivery the herniated bowel was placed in a plastic bowel bag to minimize heat and water loss, and positioned to avoid interference with venous drainage. An orogastric tube was inserted and intravenous infusion started for volume resuscitation and antibiotic administration (ampicillin and gentamicin).

After appropriate resuscitation, the infant was transferred to the operating room for closure of the gastroschisis. A primary repair (PR) was considered in all cases and the umbilical cord preserved (**Fig. 1**).

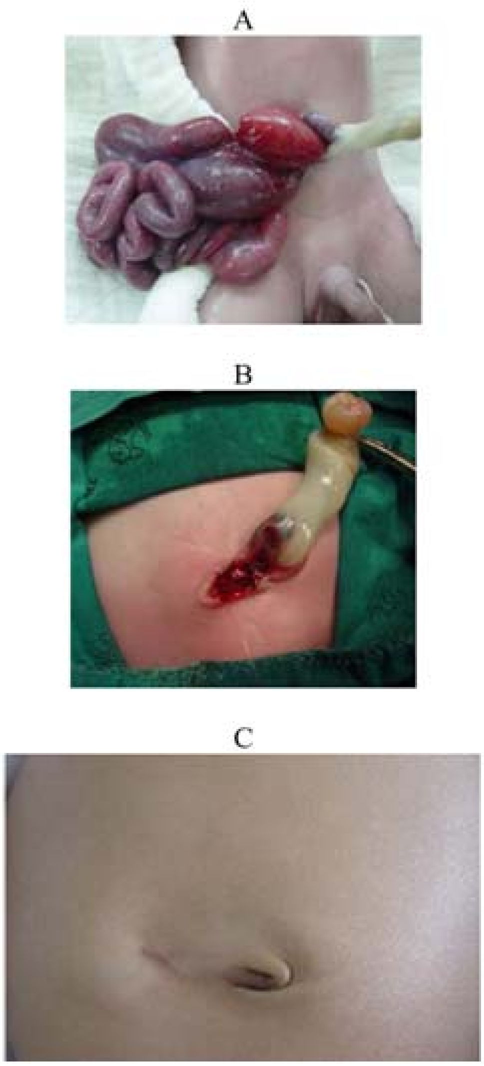

Fig. 1 Primary closure and umbilicoplasty with the preserved umbilical cord. **A**: before repair, **B:** after repair, **C:** post-operative day 30.

If this was not possible due to concerns about abdominal compartment syndrome or abdominal hypertension, then a silo pouch was fashioned by one of two methods as follows.

1) A traditional silo (TS) using white nylon mesh reinforced with adhesive plastic, and sutured directly to the fascia at the defect rim with non-absorbable sutures as shown in **Fig. 2**.

2) A sutureless elastic ring silo (SERS) using white nylon mesh and a nasogastric catheter (size 18 Fr, length 19 cm, 6-cm diameter) at its base in which both the inner and outer sides were reinforced with transparent adhesive plastic Steri-Drape membranes (3M, St. Paul, USA), as shown in **Fig. 3**.

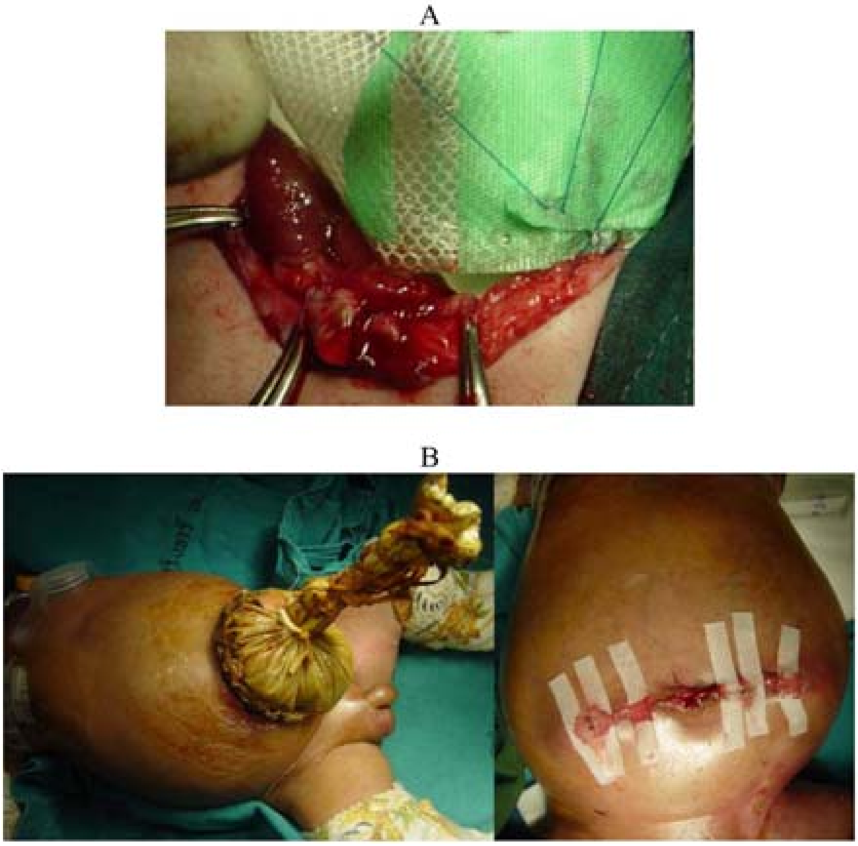

Fig. 2 The conventional suture silo method. **A:** Suturing the rim intraoperatively, **B:** staged manual reduction and post-abdominal closure.

Fig. 3 The sutureless elastic ring silo (SERS).

Then, the SERS was placed over the exposed viscera under the fascia using the sterile technique. Adhesions from the fascia to the bowel were gently disrupted manually. The umbilical cord was kept the same as in the primary repair, and the 6 cm elastic ring of the SERS could be inserted gently to fit inside the patient's abdomen. Only the surface of the transparent adhesive plastic touched the tissue. The transparent SERS was strong enough to stand in the upright position and, during the reduction procedure, the intestine could be observed clearly.

The intestine was inspected for atresias at the time of silo placement. The base of the silo was wrapped with dry gauze. The abdominal viscera were reduced progressively and the silo was closed with umbilical tape. When the bowel was completely reduced, a second-stage closure was performed in the operating room **(Fig. 4).**

Feeding was started once the orogastric contents were low (<1 mL/kg/hr) in either the primary or the staged closure. Parenteral nutrition (PN) was given until the patient was able to undertake full independent feeding.

Data analysis

Data collected included general demographic data, size of defect, associated anomalies, hospital course, mode of gastroschisis closure, duration of PN and ventilator, first feeding age, complications, and length of hospital stay (LOS).

Data is presented as mean/median, percentage, and range. Mean comparisons used unpaired Student's t test, unequal variances. A p-value of 0.05 was set for significance. Data processing was aided by the SPSS program version 12.

Results

Twenty-nine cases of gastroschisis were evaluated. Neonatal descriptors and approaches to management are highlighted in **Table 1**. There were no differences ($p > 0.05$) concerning gender, mode of delivery, APGAR scores, gestational age, birth weight, intestinal atresia, or defect size. The mode of delivery in a majority of patients was vaginal. The median APGAR scores at one and five minutes were 8 (range: 3-10) and 10 (range: 5-10), respectively. Half of the patients were born before 37 weeks' gestation and three-quarter weighed less than 2.5 kg. However, 72.4% had an appropriate gestational age (AGA), with birth weight between the tenth and ninetieth percentiles. The mean defect size was 2.5 cm (range: 2-5 cm).

Surgical intervention occurred at an average of 9 (1-24) hours post-delivery. This value is higher than might seem appropriate, as our hospital is the primary referral unit for all of southern Thailand and 25 of 29 (86.2%) of our cases were transfers, leading to delays in surgical intervention. The first group included 9/29 (31%) non-silo cases, with primary repair (PR) performed and the abdominal defect closed in an average of 50.6 (35-65) minutes. The remaining 20 patients (20/29, 69%) had TS (9/20, 31%) and SERS (11/20, 38%) procedures performed, taking on average of 80.6 (55-100) and 40 (10-80) minutes ($p = 0.007$), respectively. However, the SERS was inserted bedside in the neonatal intensive care unit (NICU) without general anesthetic in two patients, due to respiratory distress from meconium aspiration syndrome and existing endotracheal intubation. These measures were taken to ensure the airway and ventilation by inserting an orogastric tube to aspirate gastrointestinal content before and during manipulation of the intestine, supplying oxygen, and monitoring pulse oxygenation.

Until the whole intestine was returned to the abdominal cavity, gradual silo reduction in NICU took on average 7.7 (3-13) and 7.8 (5-17) days for TS, and SERS patients ($p = 0.97$), respectively. In the next and final stage, abdominal closure and umbilicoplasty procedure, the mean operative times in TS and SERS were 58.7 (60-100) and 53 (30-80) minutes ($p = 0.61$), respectively.

Functional outcome measures were duration of ventilator support, duration of PN, first feeding age, and LOS (**Table 2**). After surgery, there were no differences ($p > .05$) concerning ventilator setting and duration of ventilator. The mean ventilator support duration was 10.2 (1-48) days. Cases of successful PR were associated with earlier initiation of enteral feeding, shorter dependence on PN, shorter ventilator support duration, and LOS.

Two of 29 (6.9%) cases had associated intestinal atresias, one jejunal atresia in PR had 20 cm of jejunum with remaining transverse colon, and one in TS had colonic atresia. Both infants required a prolonged PN, delayed initial feeding, and increased LOS. Three babies were delivered in house, two TS patients, and 1 SERS patient. One in-house TS patient died at an age of six days, a term gestational age female with silo insertion at age 11.5 hours, she had severe sepsis and disseminated intravascular coagglutination (DIC).

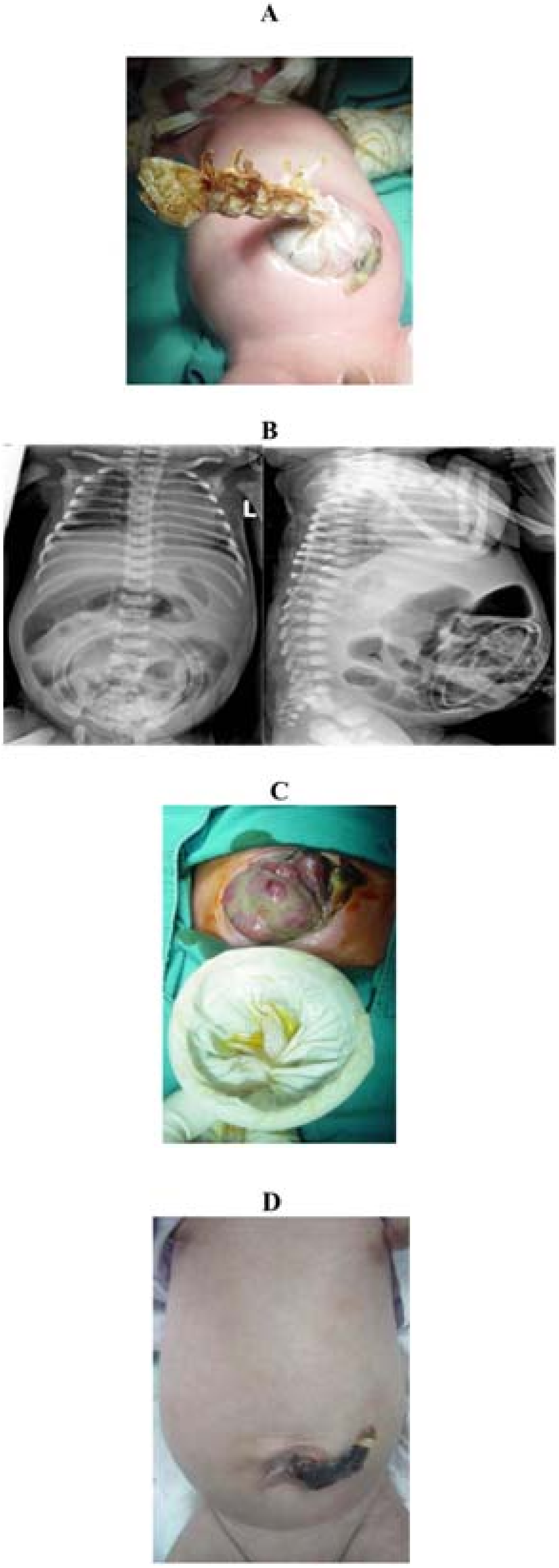

Fig. 4 Staged abdominal closure using SERS. **A**: inserting the SERS, B: abdominal film, AP: lateral view, **C**: bowel after gentle removal of the SERS, **D**: post-operative day 12.

Table 1. Patient characteristics.

	PR (n=9)	TS (n=9)	SERS (n=11)	Total (n=29)
Sex (male:female)	5:4	3:6	5:6	13:16
Mode of delivery (NL: CS)	7:2	9:0	8:3	24:5
Defect size (cm) mean (range)	2.5 (2-5)	3 (2-4)	3 (2-4)	3 (2-5)
Intestinal atresia n (%)	1 (11.1)	1 (11.1)	0	2 (6.9)
Body weight mean (range)	2.33 (1.72-2.99)	2.27 (1.81-2.96)	2.17 (1.6-2.72)	2.25 (1.6-2.99)

NL: normal labor, CS: cesarean section, BW: body weight.

Table 2. Patient outcomes: gastrointestinal outcomes, ventilator support, and length of stay (LOS).

	PR (n=9)*	TS (n=9)[#]	SERS (n=11)	Total (n=29)
TPN (days, mean/range)	12.6 (4-26)	28 (18-65)	23.4 (9-45)	21.3 (4-65)
1st feeding age (days, mean/range)	10.5 (4-23)	19.4 (11-30)	15.5 (8-31)	15 (4-31)
Ventilator (days, mean/range)	4.4 (1-16)	14 (6-29)	12 (3-48)	10.2 (1-48)
LOS (days, mean/range)	17.1 (10-31)	33.9 (22-71)	28.6 (13-55)	26.5 (10-71)

Excluded cases: *jejunal atresia with short bowel syndrome, [#]one with colonic atresia, and another with sepsis and early death at the age of six days.

Eight wound infections were identified in one PR patient, six TS patients, and one SERS patient. Problems associated with the use of a preformed silo include wound infection and silo dislodgement. One silo dislodgement was found in a SERS patient and improved without consequence after changing the SERS. In detail, a 2,040 g male was born at 39 weeks gestation by spontaneous vaginal delivery, APGAR 4,5. Immediately after birth, tracheal intubation, and ventilatory support were required for meconium aspiration syndrome. Following resuscitation, he was transferred to our institution. He was transferred to the operating room for closure of the gastroschisis at an age nine hours 40 minutes post-delivery. The size of the abdominal defect was 4 cm, and the stomach, small intestine, colon, and bladder were eviscerated. After induction of general anesthesia, primary abdominal closure was attempted. However, because of poor respiratory status and failure to reduce the eviscerated organs, a silo pouch was fashioned by SERS. The silo was closed sequentially every day in NICU without anesthesia. However, an age five days, he was respiratory distress, septicemia (*K. pneumonia*), and silo dislodgement due to accidental shearing force. He was returned to the operating room and the abdominal defect was temporary closed with Silicone sheet. After clinical was improved, an age 18 days (ventilator setting IMV, RR 15 times/min, PIP 15 and PEEP 4 cmH_2O, FiO_2 0.5), the abdominal facial closure was performed in the operating room under general anesthesia. Post abdominal closure, ventilator setting was IMV, RR 60 times/min, PIP 25 and PEEP 5 cmH_2O, FiO_2 1. After abdominal closure, he suffered hypoxic arrest in NICU and required prolong ventilator (total 48 days). His first feeding age was 31 days. LOS was 55 days. On discharge date, he was good feeding, and his body weight was 2,650 g.

Table 3. Review of previous studies.

Author	Patients (n)	IA (n) (%)	Management	Under GA	Ventilator (days)	TPN (days)	1st feeding age (days)	LOS (days)	mortality (n) (%)	UCH (n) (%)
Minkes et al. [11]	43	0	30 EC		6 (1-44)			32 (11-244)		
			13 SLS		4 (0-5)			25 (17-70)		
Driver et al. [17]	91	8 (8.8)	TC; 72 PR, 18 SR	all	4.5			42 (11-183)	7 (7.7)	
Sandler et al. [9]	10	0	6 PR, 4SR	all			12.5 (7-22)		0	6 (60)
Allotey et al. [5]	57	7 (12.3)	40 TC; 31 PC, 9 SS	all			10 (6-21)			
			13 PFS	no			12 (10-26)			
Bonnard et al. [4]	33	0	11 POC	all	3.9 (2-7)		11.7 (8-18)	32.9 (17-46)		5 (45.5)
			11 SSC	all	3.1 (1-7)		13.3 (8-17)	41.7 (17-140)		
			11 PC*; 4 PC, 7 SLS	no	3 (1-8)		14.3 (7-42)	53.5 (14-176)		9 (81.8)
Weinsheimer et al. [6]	114	11 (9.6)				29 (SD23)	15 (SD9)	41 (SD28)	4 (3.5)	
Sangkhathat et al. [18]	68	5 (7.4)	28 PR, 40 SR		5 (0-36)	19 (6-81)		27 (10-592)	4 (5.9)	
Riboh et al. [13]	47	1 (2.1)	19 TC; PR, SR	all	12.1 (3-48)		21.4 (8-53)	49.7 (20-196)		
			24 S	no	5 (1-20)		16.8 (5-38)	34.8 (12-110)		24 (100)
Payne et al. [19]	155	0	TC:118 PR, 37 SR	all		26 (7-148)		33 (8-188)		
Lansdale et al. [16]	150	8 (5.3)	139 PFS, 11 PC						5 (3.3)	
This study	29	2 (6.9)	9 PR, 9 TS, 11 SERS		10.2 (1-48)	21.3 (4-65)	15 (4-31)	26.5 (10-71)	1 (3.4)	0
Total	**797**	**42 (5.3)**								

IA: Intestinal atresia, UCH: Umbilical hernia. Emergency closure(EC)/Traditional closure (TC); Primary repair- primary repair (PR), primary operative closure (POC), and primary closure (PC). Staged repair-surgical silo (SS), stage repair (SR), staged silo closure(SSC), traditional silo (TS), and sutureless elastic ring silo (SERS). Preformed silo-spring loaded silo (SLS), and performed silo (PFS). Plastic sutureless- plastic closure (PC*), and sutureless (S).

Discussion

Several techniques are available for closure of a gastroschisis abdominal wall defect. Emergency surgery with primary abdominal closure has been the mainstay for gastroschisis [8], if intra-abdominal pressure is normal. The more common techniques for staged reduction, if primary closure fails, include the use of prosthetic materials such as an intravenous infusion bag [5], Prolene (Ethicon, Edinburgh, UK) [5], Spring-loaded silo (Bentec Medical, Woodland, USA) [4, 9, 10], SILASTIC (Dow Corning, Midland, USA) [5, 11], and Applied Alexis [wound protector and retractor system (Applied Medical Resources Corp, USA) [7, 12]].

Recently, TS has been replaced with SERS or another sutureless silo (such as described above) in which the bottom ring is placed in the abdominal cavity. The spring-loaded silo is widely used for staged reduction. Unfortunately, it is not available in Thailand. As an alternative, we use an in-house prepared silo. The material components of the SERS are inexpensive and readily available in a hospital. In addition, operating time when using a SERS device is shorter than when performing TS, which is a significant advantage. The SERS or Spring-loaded silo can be inserted without general anesthetic [4, 11, 13] or an endotracheal tube. Care must be taken to ensure the airway and ventilation by inserting an orogastric tube to aspirate gastrointestinal content before and during manipulation of the intestine, supplying oxygen, and monitoring pulse oxygenation.

For the technical point of the silo size, we chose a diameter of 6 cm as the bottom elastic ring when the abdominal defect was usually less than 4 cm in width and the range defects were 2-5 cm. The ring material should be elastic, re-expand to circular shape, and fit in the abdomen. We used a nasogastric catheter (size 18 Fr, 19 cm in length, and 6-cm in diameter). The nylon mesh was used for the silo structure since it was strong enough to stand in the upright position and, during the reduction procedure, the intestine could be observed clearly. The material components of this improvised SERS are inexpensive and readily available in a hospital. The cause of silo dislodgement was accidental shearing force in the intensive care unit. Prevention could be care of the patient in the supine position and without traction of the silo.

In the past decade, current methods of treatment have changed to the routine use of a sutureless silo [5, 8, 10-12, 14-16], preformed routine silo [5, 11, 16], and non-operative management [4, 9, 13] for infants with gastroschisis. Overall outcomes of these various managements are reviewed in **Table 3**.

In conclusion, the SERS is simple, innovative, and effective in gastroschisis patients who cannot be treated through primary closure. Our improvised SERS, constructed from readily available and inexpensive materials in any hospital, is simple, safe, and efficacious in settings such as ours, where the normal technique is not available.

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The authors have no conflict of interest to declare.

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