

The Utility of Midline Intravenous Catheters in Critically Ill Emergency Department Patients

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Study objective: Midline catheters are an alternative to more invasive types of vascular access in patients in whom obtaining peripheral access has proven difficult. Little is known of the safety and utility of midline catheters when used more broadly in critically ill patients in the emergency department (ED). These are long peripheral catheter, ranging from 10 to 25 cm in length, typically placed with assistance of ultrasound and the Seldinger's technique. We describe our experience with the use of midline catheters in the ED.

Methods: We conducted a prospective observational case series of all patients who had a midline catheter insertion attempted in the ED. We prospectively captured data on indication, technique, location, catheter type, number of attempts, overall success or failure, vasoactive use, and complications (daily catheter patency, flow, site appearance, and dwell-time complications).

Results: From January 28, 2016, to December 30, 2017, practitioners placed 403 midline catheters. Catheter insertion success was 99%, and the median number of attempts was 1 (interquartile range 1 to 1; minimum 1; maximum 3). The median number of days the catheter remained in place was 5 (interquartile range 2 to 8). Failure to aspirate occurred in 57 patients (14%; 95% confidence interval 11% to 18%). Overall, 14 patients (3.5%; 95% confidence interval 2.0% to 5.9%) experienced 15 insertion-related complications. During the study period, 49 patients (12%; 95% confidence interval 9% to 16%) experienced 60 dwell-time-related complications. Severe complications occurred in 3 patients (0.7%).

Conclusion: Midline catheters may present a feasible alternative to central venous access in certain critically ill ED patients. [Ann Emerg Med. 2019;■:1-8.]

Please see page XX for the Editor's Capsule Summary of this article.

0196-0644/\$-see front matter

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<https://doi.org/10.1016/j.annemergmed.2019.09.018>

INTRODUCTION

Background

Since the introduction of ultrasonography to assist in venous cannulation, the boundaries between central and peripheral access have become unclear. Ultrasonography has not only improved traditional peripheral and central venous line insertion success^{1,2} but also offered new methods to access the circulatory system. A larger set of peripheral veins, typically the basilic, brachial, or cephalic veins, located in the upper arm that were once too deep for direct visualization and too small for blind exploration has become a feasible option for vascular access. Initial studies have demonstrated that cannulae inserted into these deep peripheral vessels have limited durability.³ Almost half (46%) of peripheral intravenous lines fail by 24 hours.^{3,4}

The midline catheter (long peripheral catheter) offers a potential solution. It is an intravenous catheter inserted into a peripheral vein, with the tip located just proximal to the axilla (Figure 1). These catheters range from 10 to 25

cm long, have a single or double lumen, and are typically placed with ultrasonography and Seldinger's technique. Like other peripherally inserted catheters, midline catheters have demonstrated much lower infection rates compared with central venous catheters.⁵

Importance

A number of studies have demonstrated the successful use of midline catheters in the emergency department (ED),⁶⁻⁸ but these studies were small and examined their use only in patients with difficult peripheral vascular access. To date, no study to our knowledge has examined the use of midline catheters in the broad unselected cohort of ED patients, including critically ill ones.

Goals of This Investigation

In this study, we sought to describe our experience with insertion of midline catheters in a broad cohort of ED patients.

Editor's Capsule Summary*What is already known on this topic*

Midline intravenous catheters inserted in upper arm veins offer an alternative to central venous access.

What question this study addressed

What is the emergency department (ED) experience with midline intravenous catheter insertion in critically ill patients?

What this study adds to our knowledge

In this series of 403 critically ill patients requiring vascular access, midline intravenous catheter insertion was successful in 99%. Insertion and use complications occurred in 3.5% and 12% of patients, respectively.

How this is relevant to clinical practice

Midline intravenous catheters present a feasible vascular access option in select critically ill ED patients.

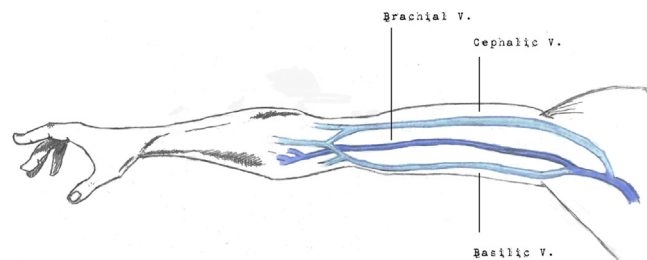


Figure 1. Anatomic location of upper extremity veins used for midline catheter insertion.

MATERIALS AND METHODS**Study Design and Setting**

We conducted a prospective observational case series of all patients who had a midline catheter insertion attempted in the ED at Stony Brook University Hospital, a 603-bed tertiary care referral center with an annual ED volume that exceeds 100,000 patients (adult and pediatric). In 2015, the hospital implemented a midline catheter program to increase vascular access options while reducing the use of central venous catheters. The policy permitted indefinite infusion of vasopressors and inotropic agents through a properly placed midline catheter. The study was approved by the hospital's institutional review board.

Interventions

Emergency medicine attending physicians and residents were trained on proper patient and vessel selection and insert techniques. Clinicians took part in a 1- to 2-hour didactic session that incorporated small lectures and simulation-based learning. Each provider was required to perform one supervised midline catheter insertion to achieve certification.

Two separate midline catheter kits were available for midline catheter insertion: the single-lumen, 10-cm, 20-gauge Bard PowerGlide (Bard Access Systems Inc, Salt Lake City, UT) catheter, and the dual-lumen, 5-French, 20-cm, trimmable Medcomp Midline (Medical

Components, Inc, Harleysville, PA) catheter. The selection of patients for midline catheter insertion and the choice of catheter type were left to the discretion of the treating clinician. If it was anticipated the patient would require the infusion of vasopressor or inotropic agents, the Medcomp midline catheter was used. Neither of the available midline catheters was heparin bonded or impregnated with antibiotics. All lines were placed with full sterile precautions, using a procedure checklist adapted from the hospital's central venous catheter insertion checklist. Although training sessions highlighted appropriate candidate vessels, formal depth or diameter thresholds were not established.

Selection of Participants

Eligible patients were identified by the treating clinician. Indications for placement of a midline catheter included difficult access, need for reliable access during an active resuscitation, or need for vasopressor or inotropic agents.

Methods of Measurement

In preparation for this project, using the hospital's electronic health record, Cerner, we built a unique procedure note designed to prospectively capture data on the indication, technique, location, catheter type, number of attempts, overall success or failure, vasoactive use, and any immediate complications. Patients were identified with this procedure note. After capture of initial insertion data, daily nursing assessments on the hospital's electronic health record were used to track the catheters' performance during the patients' hospital stay. By hospital policy, the catheters were assessed 2 times per day by the bedside nurse for the duration of their dwell time. Catheter assessments were recorded in the medical record. Each assessment included catheter patency, flow, site appearance, and any potential complications.

Two reviewers (D.E. and E.L.) independently abstracted data from medical records, using a standard data collection form. The reviewers were not blinded to the study

hypothesis. Chart abstraction used the procedure note, nursing documentation, and the patients' medical record during the hospital course.

Outcome Measures

Insertion attempt was defined as each skin puncture. Physicians reported the number of catheter insertion attempts and insertion-related complications, including failed insertion, arterial puncture or introduction, infiltration, and hematoma. We defined insertion without complication as successful line placement without any insertion-related complication. We classified vasoactive agent infusion as instances in which physician documentation indicated use of the midline catheter for vasoactive medications, the electronic health record indicated the patients had received these agents during their ED course, and no insertion of a central venous catheter was documented.

Dwell time was defined as the total time the midline catheter was in place and functioning, starting from the time documented on the physician's midline insertion note to when the line was documented in the nursing documentation as removed or to have stopped functioning. Dwell-time complications included inability to flush, catheter dislodgement, leakage from around the catheter site, insertion-site erythema, insertion-site pain, insertion-site drainage, edema, ecchymosis, superficial thrombosis, deep venous thrombosis, line-associated bloodstream infections, vesicant extravasation, skin necrosis, and neurovascular injury. Deep venous thrombosis was defined as radiographically confirmed deep venous thrombosis that occurred during the patient's hospital stay and was identified in the upper extremity on the side in which the midline catheter was placed.

Severe complications were defined as any of the following: arterial injury, vesicant necrosis, skin necrosis, or neurovascular injury. Vesicants were defined as any infusate with the potential for causing tissue injury in the event of extravasation or leakage. Vesicants were identified with the Infusion Nurses Society's list of noncytotoxic vesicant medications and solutions.⁹ All patients with an identified complication underwent a detailed chart review with a standardized data collection form to assess whether they experienced any detrimental clinical consequences from the complication.

Line-associated bloodstream infections were defined as any positive blood-culture results in the presence of clinical signs of infection, without another source in patients in whom there were signs of infection at the site of the midline catheter. In accordance with hospital policy,

midline catheters were not considered central catheters and were not subject to screening for central-line-associated bloodstream infection. Clinicians were encouraged to consider midline catheters as the source of potential infection only when there were obvious clinical indications (severe erythema, purulent drainage, etc). Because of this, a detailed chart review was performed only if nursing documentation noted any signs of potential infection, including leakage from around the catheter site, insertion-site erythema, insertion-site pain, insertion-site drainage, and edema.

Primary Data Analysis

We calculated it would require 400 patients to allow us to estimate the rate of complications with an accuracy of $\pm 5\%$ at 95% confidence to assess the safety of midline catheters. The analyses were performed with descriptive statistics. Categorical data were described with percentages and numeric data were described with medians and interquartile ranges (IQRs).

RESULTS

Characteristics of Study Subjects

Median age of the patients was 64 years (IQR 49 to 76 years), and 187 (46%) were men. The most common diagnoses associated with midline catheter insertion were sepsis or septic shock (13%), pneumonia (5%), congestive heart failure exacerbation (5%), gastrointestinal bleeding (4%), and altered mental status (4%). Four percent of patients had a central line placed during their ED stay, 10% were intubated, and 44% were admitted to the ICU (Table 1).

From January 28, 2016, to December 30, 2017, 403 midline catheters were placed. Three hundred seventy-six (96%) were placed with ultrasonographic guidance and modified Seldinger's technique, and 4% were placed with a sterile over-wire exchange of an existing peripheral catheter. One hundred eighty-seven (46%) were single-lumen catheters, whereas 213 (53%) were double-lumen ones. One hundred eighty-eight catheters (47%), 128 catheters (32%), and 59 catheters (15%) were placed in the basilic, brachial, and cephalic veins, respectively. The median catheter length was 10 cm (IQR 10 to 15 cm). The most common reasons for insertion were need for intravenous access and medication administration in 157 patients (39%), need for intravenous access alone in 104 (26%), need for intravenous access, medication administration and ongoing resuscitation in 70 (17%), medication requirement in 27 (7%), and resuscitation alone in 7 (2%) (Table 2).

Table 1. Baseline characteristics of ED patients receiving midline catheter placement.

Characteristic	No. (%)
Median age, median (IQR), y	64 (49–76)
Male sex, No. (%)	187 (46)
Comorbidities, No. (%)	
Heart failure	94 (23)
Diabetes	126 (31)
End-stage renal disease*	42 (10)
Immunocompromised†	38 (9)
Vital signs	
Pulse rate, median (IQR), beats/min	92 (76–107)
Systolic blood pressure, median (IQR), mm Hg	122 (101–145)
Diastolic blood pressure, median (IQR), mm Hg	71 (59–82)
Respiratory rate, median (IQR), breaths/min	18 (16–20)
SpO ₂ , median (IQR), %	97 (95–99)
Missing, No. (%)	3 (0.7)
ED lactate, mean (95% CI), mmol/L	2.0 (1.3–3.4)
Intubated before insertion, No. (%)	42 (10)
Missing, No. (%)	6 (1.5)
ED diagnosis* (top 5 diagnoses), No. (%)	
Sepsis/septic shock	52 (13)
Pneumonia	21 (5)
Congestive heart failure exacerbation	20 (5)
Gastrointestinal bleeding	15 (4)
Altered mental status	15 (4)
Missing	3 (0.7)
ICU admission, No. (%)	176 (44)
Central line placed in ED, No. (%)	14 (4)
Hospital mortality, No. (%)	40 (10)

*Stage 5, receiving weekly hemodialysis.

†HIV with CD4 count less than 400 cells/ μ L, cancer and actively receiving chemotherapy, organ transplant and receiving immunosuppressant medications, or long-term steroid use.

Main Results

Ninety-nine percent of the midline catheter placements attempted in this cohort were successful. Median number of attempts was 1 (IQR 1 to 1). Two hundred fifty-nine catheters (64%) were placed on the first attempt, 53 (13%) on the second, and 7 (3%) on the third, and only 1 patient (0.2%) required greater than 3 attempts for successful placement of the midline catheter. Median number of days the catheter remained in place was 5 (IQR 2 to 8 days). The mean dwell time was 6.7 days. Failure to aspirate occurred in 57 patients (14%; 95% confidence interval [CI] 11% to 18%). Ninety-eight percent of the midline catheters were inserted without complications. There were 2 failed procedures (inability to place), 1 hematoma

Table 2. Midline catheter indications and anatomic insertion site.

Characteristic	No. (%)
Indication	
Access	104 (26)
Medication	27 (7)
Resuscitation	7 (2)
Access/resuscitation	8 (2)
Medication/access	157 (39)
Medication/resuscitation	19 (5)
Medication/access/resuscitation	70 (17)
Missing	11 (2.7)
Method	
Fresh stick	376 (96)
Upgrade	15 (4)
Missing	12 (3.0)
Use of ultrasonography	376 (96)
Basilic vein	188 (47)
Left	77 (41)
Right	111 (59)
Brachial vein	128 (32)
Left	62 (48)
Right	64 (50)
Unspecified	2 (2)
Cephalic vein	59 (15)
Left	26 (44)
Right	33 (56)
Catheter type	
Single	187 (46)
Double	213 (53)
Missing	3 (0.7)
Catheter length, median (IQR), cm	10 (10–15)

development, and 1 recognized arterial cannulation that did not require intervention other than holding sustained manual pressure.

Overall, 14 patients (3.5%; 95% CI 2.0% to 5.9%) experienced 15 insertion-related complications and 49 (12%; 95% CI 9% to 16%) experienced 60 dwell-time-related complications during the study period. The majority of these complications were edema, pain, drainage, or ecchymosis around the catheter site. For a complete list of complications, see [Table 3](#). Severe complications occurred in only 3 patients (0.7%), 1 arterial cannulation and 2 vesicant extravasations. None of these complications resulted in any clinical consequences to the patients.

We examined the number of insertion attempts and number of catheter days according to anatomic insertion site (basilic, brachial, or cephalic veins) and anatomic side (right or left) and found no difference in the number of attempts or the number of catheter days ([Figure 2](#)).

Table 3. Midline catheter insertion outcome and complication.

Characteristic	No. (%)
Catheter insertion outcomes	
No. of attempts, No. (%)	1 (1-1)
No. of attempts, No. (%)	
1	234 (58)
2	53 (13)
3	7 (2)
4	1 (0.2)
Missing	108 (26.8)
Failed catheter insertion	3 (0.7)
Catheter used for vasopressor infusion	119 (29.5)
Catheter days, median (IQR)	5 (2-8)
Missing	5 (1.2)
Catheter insertion complications	
Inability to aspirate	57 (14)
Insertion-related complications	
Arterial puncture/introduction	1 (0.2)
Failed/unsuccessful	3 (0.7)
Infiltration	1 (0.2)
Hematoma	4 (1)
Symptomatic deep venous thrombosis	1 (0.2)
Dwell-time-related complications	
Inability to flush	4 (1)
Catheter dislodgement	4 (1)
Leaking	22 (5)
Erythema	5 (1)
Pain	5 (1)
Drainage	4 (1)
Edema	9 (2)
Infiltrated	1 (0.2)
Superficial thrombosis	1 (0.2)
Echymosis	3 (1)
Vesicant extravasation	2 (0.5)
Missing	9 (2.2)

LIMITATIONS

Although this was a prospective study in which all data points were determined a priori and collected prospectively, because of resource limitations we were forced to use bedside clinicians (both physicians and nurses) to record our data. Because this study was instituted alongside the introduction of midline catheters clinically, we had the opportunity to embed mechanisms of accurate data recording into the clinical work flow. Even so, it is possible the fidelity of our data is not as accurate as it would have been had we had an independent data collection system. The majority of the data we intended to capture was available through chart review. The only measurements

with significant amounts of missing data were number of attempts to obtain access (108 patients) and insertion-related complications (9 patients). It is possible that clinicians failed to include number of attempts on their procedure note out of fear of documenting a high number of attempts. If this was in fact the case, these could have biased our results in favor of a lower number of insertion attempts needed. Despite these missing data, all these patients had successful placement of midline catheters, with a low overall complication rate, so we do not believe these missing data change our underlying conclusion. As for the 9 patients without insertion-related-complication data, their charts were reviewed and no obvious complications caused by midline catheter insertion were identified.

Inhospital mortality was 10% in our cohort. A detailed chart review of these 40 patients did not indicate any whose death was related to the midline catheters themselves (ie, hospital-acquired infection or pulmonary embolism of an unknown source). Because of the observational nature of our study, we cannot state with absolute certainty that these deaths were not related to the use of a midline catheter, although it is highly unlikely.

In addition, in accordance with hospital policy, midline catheters were not considered potential sources for central-line-associated bloodstream infections, and thus were not coded as such. Investigations into the midline as a potential source of fever or positive blood culture results were pursued only if there were clinical indications to do so. Because of this, there is the potential that midline-catheter-associated bloodstream infections were not detected by nursing documentation and chart review, inflating the apparent safety of the catheters.

Finally, we used the presence of a procedure note in the electronic health record to identify patients in whom a midline catheter was inserted in the ED and cross-referenced this with the nurse documentation of the presence of a midline catheter to identify any missed cases. Cases in which the clinician attempted to place a midline catheter but failed and did not complete a procedure note would not have been captured by our data set. This limitation has the potential to make our insertion success appear better than it was.

DISCUSSION

In this study, we described our experience with midline catheter insertion in the ED. Previous studies examining the use of midline catheters in the ED examined their use only in patients with difficult access.^{3,4,6-8} In comparison, our study examined their use in a broad cohort of ED patients in whom the indication for placement was more

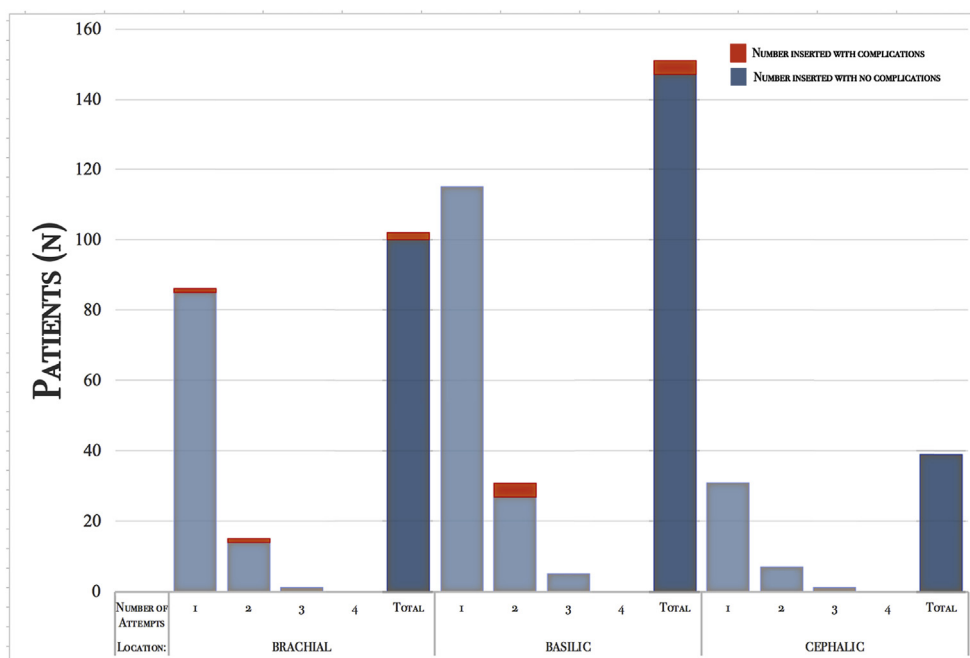


Figure 2. Number of insertion attempts and complications stratified by anatomic site.

than just difficult access. An important distinction of our series is that only a minority of patients in our study had midline catheters placed for intravenous access alone. Almost three fourths of patients required administration of medication or active resuscitation. Of the midline catheters placed for medication administration only, more than half were for vasopressor agents. Our series also included many critically ill patients, including those who were intubated, were admitted to the ICU, or who ultimately died.

Consistent with previous cohorts, our study demonstrated fairly high rates of successful insertion. Previous ED cohorts have reported overall success rates between 92% and 100% compared with 99% in our cohort.^{4,6-8} The median number of attempts, 1 to 1.5, was also similar to that in our study. The mean duration of midline catheter dwell time in our cohort was 6.7 days, ranging from 1 to 48 days. Previous studies have also demonstrated similar durability, citing mean dwell times of 7.69 to 16.4 days.^{3,5,6,8,10}

Inability to aspirate occurred in 57 of the catheters (14%) in our cohort. This outcome is fairly consistent with that in previous cohorts that have reported similar rates of inability to aspirate (11.4%).³ Although the rate of dwell-time-associated complications was 14.9%, almost all were minor: leakage from around the catheter (5%), edema (2%), insertion-site drainage (1%), insertion-site ecchymoses (1%), erythema without subsequent infection (1%), and insertion-site pain (1%). The rate of serious complications was very low, 0.7%. None of these

complications resulted in clinically important consequences for the patients. Our results are similar to what was observed in previous cohorts. Caparas and Hu¹¹ reported a complication rate of 19.9% associated with the use of midline catheters.

Vasopressors were used in 29.5% of midline catheters inserted in this series. There were 2 reports of vesicant extravasation. The first of these patients had no vasopressor agents or other vesicants in use at the event and underwent no further interventions, nor did this patient experience any complications as a result of the extravasation. The second event occurred during an infusion of norepinephrine. It resulted in plastic surgery, vascular consultations, and administration of phentolamine. The patient experienced no negative consequences from this event. A search of previous data examining the use of midline catheters with vesicants identified only 2 infiltrative events. In the study by Mills et al,⁷ this event transpired directly after a difficult insertion performed by one of their less experienced practitioners. In a study by El-Shafey and Tammam,⁴ a single midline catheter infiltrated shortly after its insertion. Both of these events occurred soon after insertion and quickly became clinically obvious. A detailed analysis concerning the subset of patients in our cohort who received vasopressors is being conducted and will be published separately.

Our results also highlight other appealing aspects of midline catheters. Consistent with previous studies, no catheter bloodstream infections associated with midline

catheter insertion were observed.^{5,12-14} We also did not observe any deep venous thromboses, but this inference may be limited because we did not conduct systematic screening for such thromboses.^{5,11,13-16} We also observed a relatively short time to line failure compared with that for ultrasonographically guided peripheral catheters.^{2,10,17-19} Bahl et al²⁰ compared standard long peripheral catheters with an 8-cm extended-dwell catheter, finding median catheter days of 4.04 for the extended-dwell catheter group compared with only 1.25 days in the long intravenous catheter group. Although we did not directly examine whether the use of midline catheters reduced the number of central lines inserted in the ED, previous studies have demonstrated that the use of midline catheters in the ICU setting led to a decrease in central venous catheter line days,¹⁰ as well as the rate of central-line-associated bloodstream infections.^{21,22}

Our study represents one of the largest cohorts of patients undergoing midline catheter placement in the ED. Our data highlight the utility of midline catheters in a broad cohort of ED patients. Midline catheters may offer an alternative to central venous access in critically ill ED patients.

Supervising editor: Henry E. Wang, MD, MS. Specific detailed information about possible conflict of interest for individual editors is available at <https://www.annemergmed.com/editors>.

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Author contributions: All authors made substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data, and drafting and revising of the study. RJS takes responsibility for the paper as a whole.

All authors attest to meeting the four [ICMJE.org](http://www.icmje.org) authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict

of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Publication dates: Received for publication May 8, 2019. Revisions received July 15, 2019; August 30, 2019, and September 13, 2019. Accepted for publication September 24, 2019.

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