Contemporary utility of diagnostic peritoneal aspiration in trauma

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BACKGROUND: Focused Assessment with Sonography for Trauma (FAST) has supplanted diagnostic peritoneal lavage (DPL) as the preferred bedside evaluation for traumatic hemoperitoneum. Diagnostic peritoneal aspiration (DPA) is a simpler, faster modification of DPL with an unclear role in contemporary practice. This study delineated modern roles for DPA and defined its diagnostic yield.

METHODS: All trauma patients presenting to our Level I center who underwent DPA were included (May 2015 to May 2020). Demographics, comorbidities, clinical/injury data, and outcomes were collected. The diagnostic yield and accuracy of DPA were calculated against the criterion standard of hemoperitoneum at exploratory laparotomy or computed tomography scan.

RESULTS: In total, 41 patients underwent DPA, typically after blunt trauma (n = 37, 90%). Patients were almost exclusively hypotensive (n = 20, 49%) or in arrest (n = 18, 44%). Most patients had an equivocal or negative FAST and hypotension or return of spontaneous circulation after resuscitative thoracotomy (n = 32, 78%); or had a positive FAST and known cirrhosis (n = 4, 10%). In two (5%) patients, one obese, the catheter failed to access the peritoneal cavity. Diagnostic peritoneal aspiration sensitivity, specificity, positive predictive value, and negative predictive value were 80%, 100%, 100%, and 90%, with an accuracy of 93%. One (2%) complication, a small bowel injury, occurred.

CONCLUSION: Despite near ubiquitous FAST availability, DPA remains important in diagnosing or excluding hemoperitoneum with exceedingly low rates of failure and complications. Diagnostic peritoneal aspiration is most conclusive when positive, without false positives in this study. Diagnostic peritoneal aspiration was most used among blunt hypotensive or postarrest patients who had an equivocal or negative FAST, in whom the preliminary diagnosis of hemoperitoneum is a critically important decision making branch point. (*J Trauma Acute Care Surg.* 2021;91: 814–819. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Diagnostic, level III.

KEY WORDS: Diagnostic peritoneal aspiration; diagnostic peritoneal lavage; focused assessment with sonography for trauma; hemoperitoneum; trauma.

Before point-of-care ultrasound became ubiquitous, diagnostic peritoneal lavage (DPL) was frequently used as a bedside tool to diagnose intraperitoneal hemorrhage after blunt trauma.[1–8] To perform a DPL, a catheter is inserted percutaneously to the peritoneal cavity, and saline is instilled. This fluid is manually lavaged throughout the peritoneal cavity and then aspirated back and analyzed in the laboratory for the presence of red blood cells. Because of the challenges in instillation and retrieval of fluid, as well as the time required for laboratory analysis and the invasive nature of this technique, DPL was not an ideal method to diagnose intra-abdominal bleeding in trauma. Diagnostic peritoneal aspiration (DPA) has been proposed as a modified version of the DPL.[9] In DPA, a catheter is inserted percutaneously to the peritoneal cavity as in DPL. However, instead of instillation and withdrawal of fluid, a syringe is used to aspirate for contents after gaining access to the peritoneal space. Aspiration of blood is considered a positive result. Although the technique remains invasive, it is significantly more straightforward than DPL and provides immediate results.

Modern rapid bedside diagnosis of intraperitoneal bleeding after trauma is largely accomplished using the Focused Abdominal Sonography for Trauma (FAST) examination, which is a noninvasive diagnostic modality.[10–12] With its introduction in the early 1990s and widespread adoption over the past three decades, FAST gradually supplanted DPL as the investigation of choice to detect intraperitoneal bleeding after trauma. In the context of widespread availability and use of FAST, it is unclear if a contemporary role for DPA persists because it is an invasive diagnostic test to achieve the same purpose. Although FAST is a useful diagnostic modality, its sensitivity and specificity are user dependent, which hinders its utility in some scenarios. Initial literature proposed that FAST and DPA could be used interchangeably to diagnose or exclude intra-abdominal bleeding in patients with concomitant pelvic fractures,[13–15] a clinical scenario in which the distinction between abdominal and pelvic bleeding represents a critical branch point in decision making and patient care. Alternatively, DPA has also been proposed to be most useful among hemodynamically unstable blunt trauma patients in whom FAST is negative or equivocal but concern for intra-abdominal bleeding persists.[9]

The primary objective of this study was to define the role of DPA in contemporary trauma practice in terms of patient selection and the clinical scenarios in which it is used at an American College of Surgeons-verified Level I trauma center. Secondary objectives were examination of the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of DPA in the diagnosis or exclusion of intraperitoneal bleeding; and delineation of the complication rates after DPA. Our hypothesis is that DPA will be used principally in hemodynamically unstable blunt trauma patients with negative or equivocal FAST examinations; that it will be highly sensitive and specific for hemoperitoneum; and that it will be used sparingly, given the widespread availability of FAST.

METHODS

This is a single-center retrospective observational study performed at our American College of Surgeons-verified Level I trauma center. All trauma patients who underwent DPA from May 1, 2015, to May 31, 2020, were included in the study. Patients were identified from the LAC+USC Trauma Registry by querying for International Classification of Diseases (ICD) procedure codes for DPA (ICD-9: 54.25; ICD-10: 0W9G3ZX, 0D9W30Z, 0D9W3ZZ, 0D9W00Z, 0D9W0ZX, 0W9G00Z, 0W9G0ZX, 0W9G0ZZ, 0W9G30Z, 0W9G3ZZ). All patients identified by these diagnosis codes were reviewed and only

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patients who underwent DPA in the trauma bay for the diagnosis or exclusion of intraperitoneal bleeding were included in the study. Patients with missing relevant documentation were excluded. Medical chart review was subsequently undertaken. Institutional Review Board approval was granted by the University of Southern California. A waiver of informed consent was approved given the retrospective observational nature of the study.

Data variables included patient demographics (age, sex, race/ethnicity); clinical data (field and initial emergency department [ED] vital signs); injury data (mechanism of injury, Abbreviated Injury Scale [AIS] by body region, Injury Severity Score [ISS]); procedures and investigations performed in the ED, including FAST and DPA results; results of computed tomography (CT) scan of the abdomen and pelvis, if applicable; operative findings, if applicable; and outcomes (disposition destination from the ED; 28-day postinjury hospital-, intensive care unit-, and ventilator-free days; in-hospital mortality; and complications from DPA).

Diagnostic peritoneal aspiration was performed using a Seldinger technique without ultrasound guidance with a commercially available kit by trauma fellows and residents under direct supervision by the attending trauma surgeon. Indications for DPA are not protocolized at our institution and therefore DPA was undertaken at the discretion of the attending trauma surgeon. Aspiration of any amount of blood was considered a positive examination. The DPA result was compared against the criterion standard of hemoperitoneum diagnosed at exploratory laparotomy or on index CT scan of the abdomen and pelvis to calculate sensitivity, specificity, PPV, NPV, and accuracy. Patients who did not survive to either exploratory laparotomy or CT scan had the diagnostic yield of DPA coded as "unknown" and were censored from the diagnostic yield calculations.

Descriptive statistics were used to summarize the patient demographics, clinical data, injury data, and outcomes. Continuous variables are presented as median (interquartile range, [IQR]) and dichotomous variables are presented as numbers (percentages). Data were collected and analyzed using IBM SPSS Statistics 23 (IBM Corporation; Armonk, NY).

TABLE 1. Patient Demographics, Clinical Data, and Injury Data

	Patients (n = 41)
Patient demographics	
Age, y	49 [29–64]
Sex, male	31 (76%)
Clinical data	
Field vital signs	
GCS	3 [3–9]
HR	86 [70–109]
SBP	90 [61–136]
First ED vital signs	
GCS	3 [3–7]
HR	69 [0–113]
SBP	97 [0–130]
Hypotensive	20 (49%)
In cardiac arrest	18 (44%)
Mechanism of injury	
Blunt	37 (90%)
AVP	13 (35%)
MVC	12 (33%)
Fall	6 (16%)
Assault	2 (5%)
MCC	1 (3%)
Other	3 (8%)
Penetrating	4 (10%)
GSW	3 (75%)
SW	1 (25%)
Injury data	
ISS	29 [22–42]
AIS	
Head and neck	4 [3–5]
Face	2 [1–2]
Chest	3 [3–4]
Abdomen and pelvis	3 [2–4]
Extremities	3 [2–3]
External	1 [1–1]

Continuous variables presented as median [IQR]. Categorical variables presented as number (percentage).

GCS, Glasgow Coma Scale; HR, heart rate (bpm); SBP, systolic blood pressure (mm Hg). Hypotensive, systolic blood pressure <90 mm Hg but not in cardiac arrest; AVP, auto versus pedestrian collision; MVC, motor vehicle collision; MCC, motorcycle collision; GSW, gunshot wound; SW, stab wound.

RESULTS

Over the approximately 5-year study period, 41 patients underwent DPA. Median age was 49 years (IQR, 29–649 years), and patients were predominantly male (n = 31, 76%) (Table 1). Patients were almost exclusively injured by blunt trauma (n = 37, 90%), particularly auto versus pedestrian collisions (n = 13) and motor vehicle collisions (n = 12).

All but three patients were hypotensive or in cardiac arrest, which were mutually exclusive categories in this study, upon arrival (Table 1). Median ISS was 29 (22–42), with the head/neck as the most severely injured body region (median AIS score, 4 [3–5]), followed by the chest, abdomen/pelvis, and extremities, all with median AIS score of 3. Half of the patients (n = 21, 51%) underwent resuscitative thoracotomy (Table 2). Overall mortality was 81% (n = 33).

Among patients undergoing DPA, the majority had a negative or equivocal FAST and were hypotensive or in cardiac arrest (n = 32) (Fig. 1). The second largest patient subgroup was comprised of those with known cirrhosis and a positive FAST (n = 4). In 39 (95%) patients, DPA was felt to be successful at accessing the peritoneal cavity. In two (5%) patients, the operating surgeon did not feel he/she had accessed the peritoneal cavity, abandoned the aspiration, and documented the DPA as "failed." One of these patients (50%) was morbidly obese. Of the remaining 39 patients, 29 (74%) had a negative DPA and 10 (26%) had a positive DPA.

In addition to the two patients with a failed DPA, 11 (27%) died before a confirmatory test for hemoperitoneum (exploratory laparotomy or CT scan) could be performed. Therefore, the diagnostic yield calculations for DPA were performed on the remaining 28 patients (Table 3). The sensitivity and specificity of DPA were 80% and 100%, respectively. The PPV and NPV were 100% and 90%, respectively, with an overall accuracy of 93%

TABLE 2. Outcomes

	Patients (n = 41)
ED procedures	
Intubation	38 (93%)
Central line	32 (78%)
Chest tube	25 (61%)
Resuscitative thoracotomy	21 (51%)
REBOA	1 (2%)
Emergent surgeries/procedures	
Exploratory laparotomy	16 (39%)
Angioembolization	6 (15%)
Extremity soft tissue	3 (7%)
Extremity vascular	2 (5%)
ICP monitor	2 (5%)
Craniotomy/craniectomy	1 (2%)
OR thoracotomy	1 (2%)
MTP activation	24 (59%)
Transfusion ≤ 4 h, units	
pRBC	7 [3–16]
FFP	7 [4–11]
Platelets	1 [1–2]
Cryoprecipitate	3 [2–4]
Mortality	33 (81%)
ED death	11 (33%)
Suspected cause of death	
TBI	9 (28%)
Exsanguination	4 (12%)
SCI	4 (12%)
MSOF	2 (6%)
Other	4 (12%)
Unknown	10 (30%)
Hospital-free days	0 [0–0]
ICU-free days	0 [0–0]
Ventilator-free days	0 [0–0]

Continuous variables presented as median [IQR]. Categorical variables presented as number (percentage).

Hospital-, ICU-, and ventilator-free days are given for the first 28 days after injury.

REBOA, resuscitative endovascular balloon occlusion of the aorta; ICP, intracranial pressure; MTP, massive transfusion protocol; pRBC, packed red blood cells; FFP, fresh frozen plasma; SCI, cervical or high thoracic spinal cord injury; MSOF, multisystem organ failure; LOS, length of stay (d); ICU, intensive care unit.

(Table 3). There were no false-positive DPAs in this study. Two false negatives occurred and are reviewed in further detail below.

While 11 (27%) patients died in the ED, 30 patients survived out of the ED: 15 (37%) who were taken directly to the operating room and 15 (37%) who underwent CT scan. Of the 15 patients who underwent immediate operation, 8 had true-positive DPAs and underwent exploratory laparotomies for hemorrhage control. Four patients with true-negative DPAs underwent immediate operations: one for repair of a blunt cardiac rupture; one for pneumonectomy following a gunshot wound; one for hemorrhage control and debridement of a traumatic amputation; and one patient for exploratory laparotomy after sustaining the one complication of DPA in this series, described in further detail below.

The remaining three patients who underwent immediate operation were comprised of the two patients with false-negative DPAs and one with a failed DPA. After equivocal FASTs, negative DPAs, normal pelvic x-rays, and either chest x-ray or resuscitative thoracotomy that did not identify a source for hemodynamic instability after blunt trauma, the two false-negative DPA patients were taken to the operating room for exploratory laparotomy to exclude intra-abdominal hemorrhage. Both of these patients were found to have hemoperitoneum with severe liver injuries necessitating packing and temporary abdominal closure. We were unable to identify any specific patient or provider factors that may have contributed to these two false-negative DPAs. Both patients died, one on the first hospital day after arriving in cardiac arrest and with near complete cervical spinal cord transection identified on postoperative CT scan in addition to the above liver injury managed with packing via exploratory laparotomy; and one after 27 days in hospital from multisystem organ failure due to sepsis. The final patient who was taken to the operating room following DPA without a CT scan was one of the two patients with a failed DPA. This patient was taken for exploratory laparotomy, which identified a colonic injury necessitating resection but no intra-abdominal bleeding. This patient survived and was discharged home.

One complication of DPA occurred (2%) in an unstable trauma patient after auto versus pedestrian collision. This patient had a negative FAST and DPA, as well as chest and pelvic x-rays that did not reveal the cause of his hypotension. He was taken for exploratory laparotomy given the hemodynamic instability of unclear source after high-speed blunt trauma. Exploratory laparotomy was negative apart from a catheter-sized hole in the small bowel, which was presumed to be from the DPA and was managed with imbrication. This patient ultimately died of severe TBI.

DISCUSSION

In this study, DPA was used almost exclusively among unstable blunt trauma patients. This is intuitive but helpful to delineate. Unstable patients who are injured by penetrating trauma typically do not have multicavitary injuries simultaneously contributing to hemodynamic instability, whereas in blunt trauma, it is critical to rapidly identify the body cavity that harbors the exsanguinating injury. In addition, the fact that most study patients undergoing DPA were hemodynamically unstable is logical, with noninvasive imaging modalities preferred over invasive procedures for confirmatory testing in the stable patient.

Diagnostic peritoneal aspiration was used predominantly among two specific subsets of unstable blunt trauma patients. The first group was comprised of patients with an equivocal or negative FAST examination. In this clinical context, a positive FAST result would typically direct the patient to the operating room. An equivocal or negative FAST examination in these patients is a challenging clinical scenario, particularly if no other sources of hemodynamic instability are detected on primary survey. In these patients, a rapid, bedside test to complement the FAST examination is useful and DPA fills that role.

The second population of unstable blunt trauma patients undergoing DPA was patients with a known history of cirrhosis with a positive FAST. In these patients, ascites is a likely source of a false positive FAST examination and hemodynamic changes after trauma in cirrhosis can be more insidious than in a healthy individual. In these patients, DPA was again a useful confirmatory test to identify hemoperitoneum as opposed to simple ascites as the cause for the positive FAST. Particularly when one considers the

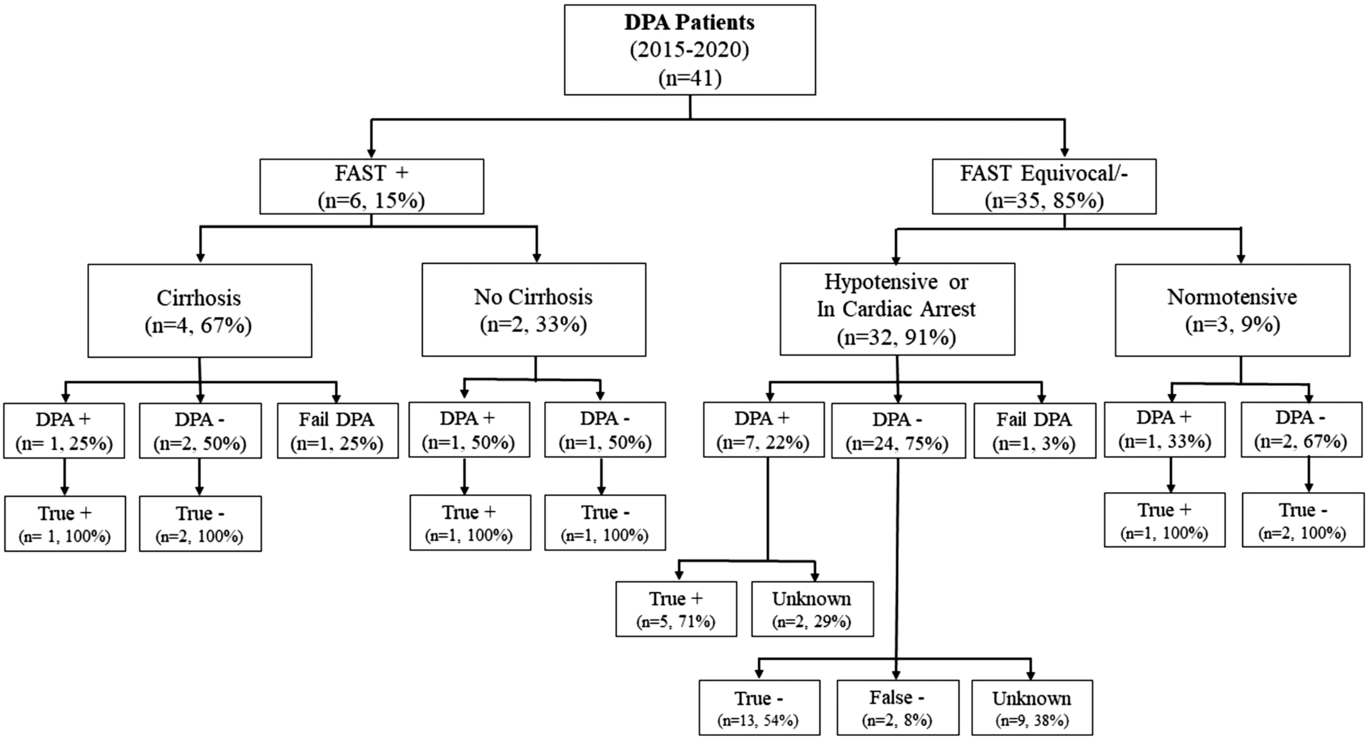

Figure 1. Flow of patients through study. +, positive. –, negative.

finding that the typical patient undergoing DPA in this study had severe injuries in four different body regions (the head/neck, chest, abdomen/pelvis, and extremities), this underlines the need to rapidly identify the body cavity contributing most to a patient's instability.

It is also noteworthy that DPA was more specific than sensitive. Put differently, if blood is aspirated on DPA, this is reflective of underlying hemoperitoneum in 100% of cases. There were no DPA false positives in this series. However, the interpretation of a negative DPA is more challenging. The sensitivity and NPV of DPA were 80% and 90%, respectively, meaning that a negative DPA does not exclude hemoperitoneum. Decision making for such patients must therefore be individualized according to the persistence of clinical concern for intra-abdominal bleeding and the patient's hemodynamic response to ongoing resuscitation as investigative efforts are underway.

TABLE 3. Diagnostic Yield of DPA

	Hemoperitoneum Positive	Hemoperitoneum Negative	Total
DPA-positive	8	0	8
DPA-negative	2	18	20
Total	10	18	28

DPA diagnostic yield: Sensitivity 80%, Specificity 100%, PPV 100%, NPV 90%, Accuracy 93%

DPA results were considered positive if any amount of blood was aspirated. A criterion standard of hemoperitoneum at exploratory laparotomy and/or on CT scan of the abdomen was used.

Although all 41 patients in this study underwent DPA, 11 died before exploratory laparotomy or CT scan could be undertaken and are excluded from this analysis due to lack of criterion standard for diagnosis. DPA was also unsuccessful at accessing the peritoneal cavity in two patients and these patients were therefore also censored from these calculations.

Lastly, both failure and complication rates were exceedingly low after DPA. One of two cases in this series where the DPA catheter could not be placed into the peritoneal cavity occurred in a morbidly obese patient. It is intuitive that body habitus may hinder the DPA procedure and clinicians may therefore opt to forgo this diagnostic test in a patient with unfavorable anatomy. Only one DPA complication occurred, which was a hollow viscus injury diagnosed at exploratory laparotomy in a hemodynamically unstable patient after high-speed auto versus pedestrian collision. This low rate of complications suggests that, when DPA is indicated, clinicians should not be reticent about performing this procedure.

Our study findings suggest that although DPA and FAST may once have been considered competing investigations, in contemporary trauma practice, they can be considered complementary investigations. Because FAST is noninvasive and carries a diagnostic accuracy that approaches 100%,[10–12] it is the clear criterion standard test to screen a patient for intraperitoneal or intrapericardial fluid. If the FAST is nondiagnostic in an unstable patient, that is, is either equivocal or is negative in a patient without alternate causes of instability identified in the trauma bay, a DPA should be pursued next as a complementary investigation to the FAST. Although the diagnostic yield of DPA in this study was slightly better or comparable to the diagnostic yield of DPL based on existing literature[1,2,6] with comparable rates of complications,[2,16,17] DPL carries significant disadvantages when compared with DPA that arguably render DPL obsolete in modern trauma care. These disadvantages of DPL include increased time for performance and fluid analysis, as well as confounding of CT results if performed after a DPL.[18]

On the basis of our findings, we propose the following algorithm for the use of DPA in contemporary trauma practice, which will require validation with further study. Unstable blunt trauma patients undergo a FAST examination as an adjunct to the primary survey. If the abdominal FAST is positive, these patients should undergo immediate exploratory laparotomy for hemorrhage control. If the FAST is negative or equivocal, these patients should undergo a rapid screen for alternate sources of instability via chest and pelvic x-rays. If these investigations do not provide an explanation for the patient's hemodynamic abnormalities, we recommend DPA as the next investigation. A positive DPA directs these patients for immediate exploratory laparotomy and hemorrhage control. A negative DPA is a much more challenging scenario, in which the surgeon must use his or her judgment to either undertake exploratory laparotomy regardless, to exclude intra-abdominal (including retroperitoneal) bleeding; or to pursue cross-sectional imaging to investigate for severe traumatic brain injury (TBI) or high spinal cord injury, both of which can cause hemodynamic abnormalities.

This study has several limitations. The most important limitation is the retrospective observational study design, which may obscure the clinical rationale for performance of DPA. Furthermore, the single-center nature of this study limits the number of patients studied, making it unclear if these results are generalizable on a broader scale or if the underlying practice patterns are specific to a single institution. Next, DPA was performed without ultrasound guidance in this series. Particularly in settings where ultrasound is readily available, such as the modern trauma bay, consideration could be made to performing DPA under ultrasound guidance. This may have had an impact on the rates of failure and complications and should be further studied in the future. Lastly, the lack of criterion standard diagnosis for hemoperitoneum in one third of study patients hinders our sensitivity and specificity calculations for DPA. In the future, a large multicenter prospective study could be performed to address these limitations. If possible, such a study should include autopsy data in order to avoid censoring patients from statistical analysis after death in the ED because of unknown presence or absence of hemoperitoneum.

In summary, DPA has a persistent role in the diagnosis of hemoperitoneum after trauma in the era of the widespread use of FAST. Because of its invasive and highly specific nature, we suggest the primary role for DPA should be among unstable blunt trauma patients with an equivocal or negative FAST examination and no other obvious sources of instability identified on physical examination or via adjuncts to the primary survey, including chest and pelvic x-rays. Diagnostic peritoneal aspiration is also useful among patients with known cirrhosis and a positive FAST examination to distinguish between simple ascites and traumatic hemoperitoneum. Future study of DPA should consist of multicenter study to evaluate its use in a variety of practice settings to gain a broader understanding of its contemporary role in trauma.

AUTHORSHIP

M.S. provided the study concept. M.S., N.O., B.E., and L.K. performed the data collection. M.S. and N.O. performed the data analysis. M.S., D.H.C., L.L., and K.I. performed the data interpretation. All authors participated in writing and critically reviewing the final article.

DISCLOSURE

The authors declare no funding or conflicts of interest.

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