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Errors in cervical spine immobilization during pediatric trauma evaluation

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ABSTRACT

Background: The purpose of this study was to identify factors during trauma evaluation that increase the likelihood of errors in cervical spine immobilization ('lapses').

Materials and methods: Multivariate analysis was used to identify the associations between patient characteristics, event features, and tasks performed in proximity to the head and neck and the occurrence and duration of a lapse in maintaining cervical spine immobilization during 56 pediatric trauma evaluations.

Results: Lapses in cervical spine immobilization occurred in 71.4% of patients ($n = 40$), with an average of 1.2 ± 1.3 lapses per patient. Head and neck tasks classified as oxygen manipulation occurred an average of 12.2 ± 9.7 times per patient, whereas those related to neck examination and cervical collar manipulation occurred an average of 2.7 ± 1.7 and 2.1 ± 1.2 times per patient, respectively. More oxygen-related tasks were performed among patients who had than those who did not have a lapse (27.3 ± 16.5 versus 11.5 ± 8.0 tasks, $P = 0.001$). Patients who had cervical collar placement or manipulation had a two-fold higher risk of a lapse than those who did not have these tasks performed (OR 1.92, 95% CI 0.56, 3.28, $P = 0.006$). More lapses occurred during evaluations on the weekend ($P = 0.01$), when more tasks related to supplemental oxygen manipulation were performed ($P = 0.02$) and when more tasks associated with cervical collar management were performed ($P < 0.001$).

Conclusions: Errors in cervical spine immobilization were frequently observed during the initial evaluation of injured children. Strategies to reduce these errors should target approaches to head and neck management during the primary and secondary phases of trauma evaluation.

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Introduction

The initial evaluation is a critical phase in the care of injured patients. In several studies, more than 40% of preventable or potentially preventable deaths have been attributed to errors during this phase.^{1,2} Although a standardized evaluation and management protocol (Advanced Trauma Life Support) has been shown to improve outcomes related to trauma evaluation,³ studies using video review have found more than 10 deviations from the Advanced Trauma Life Support protocol per event.^{4,5} Most of these deviations are variations addressing the unpredictability of injured patients and their response to treatment or occur because of acceptable provider preference in managing injured patients. Up to 40% of these deviations, however, can be classified as “errors” and may be directly associated with adverse outcomes, including long-term disability and death.^{1,2,4} In a previous study, we identified failure to properly maintain in-line cervical spine immobilization (“lapse”) as a frequent error during trauma evaluations at our hospital.⁶ Although the benefits and potential harm of cervical immobilization after blunt trauma has been recently reassessed,^{7,8} its use remains standard practice because of the lack of high-level evidence establishing the safety of restricting its use.^{3,9}

Root-cause analysis is a common method for determining the potential causes of harmful events, but this approach has limited utility for determining risk factors associated with adverse events that are rare.^{10,11} Analysis of near-miss events is an alternative approach to root-cause analysis when errors potentially leading to an adverse event are common but when direct harm to the patient from these errors is infrequently observed because of patient resilience, mitigation, or chance.¹² This strategy is appropriate for determining the potential causes of lapses because worsening neurological injury from improper cervical spine immobilization is rare despite lapses being common. As factors associated with near-miss events and events that propagate to the patient and cause harm may be similar, studying near-misses related to cervical spine immobilization may aid in the development of strategies that will reduce the risk associated with this type of error.¹³

The purpose of this study was to determine factors associated with errors in cervical spine immobilization during trauma evaluation. We used video review to identify process variables associated with these errors. Video review has benefits over retrospective chart review and even real-time observation because it provides insight into events that may not be documented in the chart or are difficult to identify by direct in-person observation. We used the results of this analysis to identify strategies for reducing or mitigating errors in cervical spine immobilization with the goal of preventing complications related to their occurrence.

Materials and methods

Study setting

Children’s National Medical Center is a level I pediatric trauma center serving the greater Washington, DC region and

verified by the American College of Surgeons, State of Maryland and the District of Columbia. About 600 injured children each year are evaluated in the emergency department by the trauma team based on pre-hospital triage criteria. The trauma rooms are equipped with a video recording system that records each event. The use of video recordings has been approved for research by the Institutional Review Board at Children’s National Medical Center. Consent from patients or their parent or guardian is obtained before reviewing videos.

Data sources

During a 5-month period (August–December 2014), 197 children sustaining a blunt traumatic injury presented as trauma activations. Among these 197 evaluations, 68 were excluded from this study because of poor video quality or unintended erasure of the video, and an additional 35 were not reviewed because of inability to obtain consent. We further excluded 35 patients who were transferred from another hospital because of variability in pre-transfer cervical spine imaging and indications for cervical spine stabilization in this group. Three events were identified where members of the research team played a role in patient care and were therefore also excluded. The final data set for this study included videos from 56 events.

Video review was performed to identify errors in in-line stabilization of the cervical spine. The determination of the need for cervical stabilization was made by the surgical team leader based on mechanism of injury using an established cervical spine management protocol at our hospital. We assessed for the occurrence of lapses between the time of entry of the patient to the trauma bay until either the cervical spine was cleared for removal of the collar based on clinical or radiographic criteria or the patient departed the trauma bay if the cervical spine was not cleared. A complete lapse was defined as any time the patient’s head and neck were not immobilized by a team member’s hands or by an assistive device such as a cervical collar. Incorrect stabilization was defined as an attempt at immobilization that would not immobilize the neck in case of movement. Examples of incorrect stabilization included placing the hands on the crown of the head, stabilizing the neck with one hand or securing a cervical collar only on one side. When no team member was performing manual cervical spine immobilization, the team member at the head of the bed was identified as the person responsible for maintaining cervical spine immobilization. Videos were also reviewed for tasks performed near the head and neck that were potentially associated with lapses, including preparing, providing, maintaining, and removing passive supplemental oxygen, otoscopic examination, turning the patient to inspect the back (‘log roll’), cervical spine examination, cervical collar placement or exchange and intubation. The occurrence of each task and whether it was performed during a lapse was determined by video review.

Error acknowledgment, compensation and impact were also assessed using video review. Error acknowledgment was defined as either verbal instruction to correctly stabilize the cervical spine or a non-verbal signal, such as placement of hands in the correct position. Error compensation was defined

as a team member taking action to correctly stabilize the cervical spine, such as replacing a collar removed for a neck examination. A team member could compensate for an error without acknowledgment. For example, manual in-line stabilization may be interrupted for placement of a nasal cannula and be immediately resumed once the cannula is in place, without acknowledgment of the lapse by any team member. Error impact was defined as any observable movement of the patient's head or neck during the lapse.

The occurrence of a lapse was compared among patients with different patient and event features using data from the trauma database and medical chart review. Comparison groups included age, gender, Injury Severity Score (classified as either <10 or ≥ 10), GCS motor score and the presence of a pediatric surgical fellow or attending versus a fourth-year surgical resident as the leader directing the event. We also included comparisons based on team notification (with or without pre-arrival notification of the patient), time of day (day shift [7 AM – 7 PM] versus night shift) and day of week (weekday versus weekend) because of previously identified associations of these variables with trauma team performance.^{14,15} We reviewed the medical record and our trauma performance improvement database to identify any cervical spine injury diagnosis or suspicion based on imaging or specialty consultation.

Data analysis

Differences between the events with lapses and those without lapses were assessed using the Pearson's χ^2 test for binary variables and the Student's *t*-test for continuous variables. Multivariate logistic regression was used to assess the association between patient and event features and performed tasks and the presence of a lapse. Multivariate linear regression was used to assess the association between patient and event features and performed tasks with the number of lapse occurrences and the total duration of lapses. We defined statistical significance at $P < 0.05$. Analyses were performed using Stata/SE 12.0 (College Station, TX).

Results

Over a 5-mo period, 56 children sustaining injuries from a blunt mechanism were assessed as trauma activations and eligible for inclusion in this study. The average age of the patients was 7.2 ± 4.3 y and most patients were male ($n = 44$, 78.6%). Most patients presented during the day shift ($n = 42$, 75.0%) and on a weekend ($n = 34$, 60.7%). Although all patients met trauma activation criteria, most (95%) had an Injury Severity Score <10 . Twenty-three patients (41.1%) had injuries severe enough to result in intracranial bleeding, concussions or fractures to the skull, face or mandible (Table 1). Most patients arrived with a cervical collar in place ($n = 46$, 82.1%; Table 1).

Forty patients (71.4%) had at least one lapse in cervical spine immobilization during their evaluation, with 15 of the 40 patients (37.5%) having more than one lapse. The average number of lapses was 1.2 ± 1.3 (range 0-7) per patient. Among the 40 patients in which at least one lapse occurred,

an average of 1.7 ± 1.3 lapses per patient was observed. No difference in age or gender, pre-arrival notification, team leader level or the presence of a cervical collar on arrival was observed between evaluations with and without a lapse. Individual lapses lasted an average of 42.0 ± 60.6 s (range 1-409 s), with a combined duration in evaluations with a lapse averaging 72.5 ± 94.1 s (range 5-564 s). The combined duration of all lapses was not associated with age, injury severity or team leader level (Table 2). Among the 69 identified lapses, 11 (15.9%) were acknowledged and 42 (60.9%) were compensated for by a team member. Four error acknowledgments were not associated with compensatory actions (36.4%). The patient's head or neck moved 17 times (24.6%) during a lapse ('error impact'). Among 40 patients who had a lapse, 32 (80.0%) underwent plain X-ray imaging of their neck before leaving the trauma bay, accounting for 76.2% of all patients who required cervical spine imaging at some point during their trauma evaluation and hospitalization ($n = 42$). Although no patient in this cohort had a cervical spine fracture, four patients had other neck injuries resulting in further radiographic imaging and continuation of a cervical collar after hospital discharge (Table 1).

Among the studied tasks, those classified as oxygen manipulation were the most commonly performed, averaging 12.2 ± 9.7 occurrences per patient. Maneuvers related to neck examination and cervical collar manipulation were the next most frequently performed tasks, occurring an average of 2.7 ± 1.7 and 2.1 ± 1.2 times per patient, respectively. Patients who had cervical collar placement or manipulation in the trauma bay had an almost two times higher risk of a lapse than patients who did not have these tasks performed in the trauma bay (OR 1.92, 95% CI 0.56, 3.28, $P = 0.006$). A lapse was significantly associated with tasks classified as cervical collar replacement and new cervical collar placement ($P = 0.002$ and $P = 0.04$, respectively) but not cervical collar removal. More oxygen-related tasks were performed among patients who had a lapse than those who did not have a lapse (27.3 ± 16.5 versus 11.5 ± 8.0 tasks, $P = 0.001$; Table 3). More lapses occurred during weekend events ($P = 0.01$), when more tasks related to supplemental oxygen manipulation were performed ($P = 0.02$) and when a higher number of tasks associated with cervical collar management occurred ($P < 0.001$; Table 2). A higher combined duration of all lapses was associated with a GCS motor score less than six ($P = 0.002$) but not with other factors (Table 2).

Five different team member roles were observed to be responsible for maintaining cervical spine immobilization. These team roles included respiratory therapists, nurses, emergency department technicians, anesthesiologists, and emergency medicine attendings or fellows. Respiratory therapists ($n = 37$) were the most frequent team member at the head of the bed when a lapse occurred, followed by anesthesiologists ($n = 5$) and emergency medicine physicians ($n = 3$). No significant association was observed between the presence of any individual in a specific team role at the head of the bed and the occurrence of a lapse. The number of lapses was also not associated with the role of the team member at the head of the bed.

Table 1 – Summary statistics.

Resuscitation feature	All resuscitations (n = 56)	Resuscitations without lapses (n = 16)	Resuscitations with lapses (n = 40)	P-value
Male (n, %)	44 (78.6)	11 (68.8)	33 (82.5)	0.26
Age (mean ± SD)	7.2 ± 4.3	6.3 ± 3.7	7.6 ± 4.5	0.30
ISS				
Median ISS (interquartile range)	2 (1-5)	1 (1-5)	3 (1-7)	0.30
Weekend activation	22 (39.3)	6 (37.5)	16 (40.0)	0.86
Daytime activation	42 (75.0)	10 (62.5)	32 (80.0)	0.17
No pre-arrival notification	16 (28.6)	3 (18.8)	13 (32.5)	0.30
Surgical attending/fellow as leader	25 (44.6)	7 (43.8)	18 (45.0)	0.93
Junior resident present	45 (81.8)	15 (93.8)	30 (75.0)	0.14
Arrived with cervical collar	46 (82.1)	12 (75.0)	34 (85.0)	0.38
Mechanism of injury				
Motor vehicle collision	16 (28.6)	6 (37.5)	10 (25.0)	0.82
Pedestrian struck	20 (35.7)	6 (37.5)	14 (35.0)	
Fall	7 (12.5)	1 (6.3)	6 (15.0)	
Bike/motorbike/ATV accident	9 (16.1)	2 (12.5)	7 (17.5)	
Other	4 (7.1)	1 (6.3)	3 (7.5)	
Head and neck injuries				
Fracture of skull or intracranial bleed	5 (8.9)	1 (6.3)	4 (10.0)	0.66
Fracture of face or mandible	3 (5.4)	1 (6.3)	2 (5.0)	0.85
Concussion	18 (32.1)	3 (18.8)	15 (37.5)	0.18
Neck sprain	4 (7.1)	2 (12.5)	2 (5.0)	0.19
Laceration or abrasion of scalp or face	23 (41.1)	11 (68.8)	12 (30.0)	0.008

ISS = Injury Severity Score; SD = standard deviation.

Discussion

Among patients sustaining a cervical spine injury, up to 35% will have an associated neurological injury.¹⁶⁻¹⁸ Although most of these neurological injuries are stable or improve over time, significant declines in neurological status have been reported, with 28.1% of these declines occurring during transfer from the scene of injury to the hospital and 53.1% occurring during hospitalization.¹⁹ In one study, over half of patients with major neurological deterioration after spinal trauma did not have an initially suspected spinal injury, leading to the suggestion that deterioration was related to the lack of immobilization, inadequate immobilization, or patient movement.¹⁹ It remains unclear if cervical motion after the original injury, secondary injury or both lead to worsening neurological status in the setting of a cervical spine injury.²⁰ Although the impact of routine pre-hospital cervical spine immobilization has recently been reassessed, large well-designed prospective studies have not been performed that establish the benefits and harms of this practice or that define populations who will benefit most from its use.⁹ Because the causes of worsening neurological status after cervical injury are difficult to determine, it remains standard practice to maintain cervical spine immobilization for patients whose mechanism of injury suggests a possible cervical spine injury until an injury can be ruled out.^{3,9}

Our prior work showed that failure to provide appropriate cervical spine alignment of injured children was the most common process error during trauma evaluations.⁶ Because cervical spine injury occurs in <2% of children sustaining blunt trauma,^{16,17,21} workflow analysis of cervical spinal immobilization practices in a cohort of children with cervical spine injuries is infeasible. We evaluated factors associated with lapses in a population at low-risk for cervical injury but with a high frequency of lapses, with the goal of identifying potential strategies for preventing these errors and minimizing the risk of injury propagation. Lapses can range from inappropriate hand location to no attempt at stabilization. Because the specific movement leading to secondary neurological injury after a cervical spine injury is not known, all forms of lapses can be considered near-misses because each leads to ineffective cervical spine immobilization. Although these errors have minimal impact on most children evaluated in this setting, the use of this type of near-miss analysis is a feasible approach for identifying the cause of errors that have a high potential for harm in a small cohort of affected patients with a cervical spine injury.

Because cervical immobilization makes the head and neck less accessible, coordination of movement among team members who are performing tasks in proximity to this area is required. The cervical spine is best manually immobilized when the patient's trapezius muscles are cupped with the

Table 2 – The relationship between lapses and patient and resuscitation features and activities.

Variables	Association with lapse Odds ratio (95% CI)	P-value	Duration of Lapse Odds ratio (95% CI)	P-value	Number of Lapses Odds ratio (95% CI)	P-value
Patient features						
Age (y)	0.04 (–0.24 to 0.32)	0.79	0.75 (–5.26 to 6.77)	0.80	0.004 (–0.07 to 0.08)	0.91
ISS ≥ 10	1.58 (–2.52 to 5.67)	0.45	–19.27 (–99.87 to 61.33)	0.63	–0.10 (–1.13 to 0.92)	0.84
GCS motor = 6	2.67 (–1.52 to 6.86)	0.21	–164.72 (–263.89 to –65.55)	0.002	–0.01 (–1.27 to 1.26)	0.99
Resuscitation features						
Attending/fellow leader	0.81 (–1.62 to 3.24)	0.52	8.19 (–41.63 to 58.02)	0.74	0.36 (–0.27 to 1.00)	0.25
Activation without pre-notification	1.65 (–0.98 to 4.29)	0.22	46.05 (–9.91 to 102.01)	0.10	0.19 (–0.52 to 0.90)	0.59
Weekend activation	1.17 (–1.66 to 4.00)	0.42	1.90 (–53.43 to 57.24)	0.95	0.93 (0.23 to 1.64)	0.01
Daytime activation	–0.40 (–2.71 to 1.90)	0.73	24.49 (–32.41 to 81.39)	0.39	–0.45 (–1.17 to 0.27)	0.22
Resuscitation activities						
Oxygen manipulation	0.02 (–0.09 to 0.14)	0.68	–0.61 (–3.30 to 2.09)	0.65	0.04 (0.01 to 0.08)	0.02
Neck examination	–0.54 (–1.13 to 0.05)	0.07	–2.24 (–16.98 to 12.50)	0.76	–0.16 (–0.35 to 0.02)	0.09
Otосcopy	–0.50 (–1.18 to 0.19)	0.16	0.63 (–17.69 to 18.95)	0.95	0.02 (–0.21 to 0.25)	0.87
Cervical collar manipulation	1.92 (0.56 to 3.28)	0.006	14.88 (–4.91 to 34.68)	0.14	0.62 (0.37 to 0.87)	<0.001
Log roll	2.37 (–1.96 to 6.70)	0.28	–2.88 (–65.54 to 59.77)	0.93	–0.0005 (–0.80 to 0.80)	1.00
Intubation	0.03 (–2.59 to 2.64)	0.98	–7.46 (–24.31 to 9.39)	0.38	0.04 (–0.17 to 0.26)	0.70

ISS = Injury Severity Score; GCS = Glasgow Coma Scale; CI = confidence interval.

hands and when the head and neck are maintained in a neutral position between the forearms.^{3,22} Manual immobilization of the cervical spine may be needed if the patient arrives without a collar, when a cervical collar needs to be removed for examination or when a collar needs to be exchanged. We identified a longer duration of lapses in patients with abnormal GCS motor scores, suggesting that immobilization technique may contribute to lapses because these patients are less likely to move on their own. Although interfering less than manual immobilization, a cervical collar also limits access to the head and neck region. As a team transitions from one method of cervical spine immobilization to the other, every effort should be made to eliminate the possibility of a lapse occurring through careful and well-communicated task performance.

In this study, we observed that lapses occurred for most patients. Although many lapses were brief, we observed an individual lapse that lasted more than 6 min and an event with a combined lapse duration of more than 9 min. Although it could not be assessed quantitatively using video review, cervical motion was frequently observed when lapses occurred. Most errors were not acknowledged by the team leader or others who were not maintaining cervical spine immobilization, and only about half of lapses were recognized by the team member whose role was to immobilize the cervical spine. These findings suggest that a large number of lapses are not corrected either due to a lack of recognition by team members or team members who observe the lapse but do not verbalize its occurrence to the team. Although this cohort was at low-risk for cervical injury, and no patient was

observed to have long-term consequences from a lapse, the frequency and duration of lapses and their association with cervical movement supports classifying these errors as near-miss events because of the potential consequences if occurring in the presence of a cervical spine injury.

At many institutions, trauma team members are assigned tasks in advance based on their role to ensure appropriate expertise of required tasks and to distribute workload. Even when maintenance of cervical spine immobilization is assigned, the individual responsible for the task may not be available to perform this task if they have other responsibilities. The team leader may designate another team member to immobilize the cervical spine based on proximity to the patient or availability, which may lead to errors in proper technique if the selected team member is not focused on or trained in proper cervical spine immobilization. Although training all roles in the proper performance of cervical spine immobilization is needed, we did not observe that team members who incorrectly maintained cervical spine immobilization verbalized a lack of knowledge or lack of comfort in performing this task. This observation suggests that training all team members in proper cervical spine stabilization may need to occur more frequently to sufficiently reduce lapses.

We observed that the respiratory therapist, a role with responsibilities centered around the head of the bed and related to the airway rather than cervical spine immobilization, was the team member most often immobilizing the neck. An analysis of tasks performed in proximity to the head and neck showed that those related to oxygen administration

Table 3 – Resuscitation tasks and their association with lapse occurrence and duration.

Task category	Number of tasks			Duration of lapse (s)			
	All resuscitations	Not associated with lapse	Associated with lapse	P-value	Not associated with Lapse	Associated with lapse	P-value
Oxygen manipulation	12.2 ± 9.7	11.5 ± 8.0	27.3 ± 16.5	0.001	42.3 ± 51.8	55.3 ± 36.6	0.63
Intubation	0.4 ± 1.9	8	12	1.00	0	212	1.00
Neck examination	2.7 ± 1.7	2.7 ± 1.6	3.2 ± 1.4	0.29	43.4 ± 97.2	66.5 ± 31.0	0.39
Collar manipulation	2.1 ± 1.2	2.0 ± 1.0	2.5 ± 1.0	0.11	42.7 ± 69.4	68.5 ± 101.1	0.30
Otoscopy	1.4 ± 1.3	2.4 ± 0.8	2	1.00	57.8 ± 109.1	66	1.00
Log roll	1.1 ± 0.4	1.1 ± 0.4	1	1.00	52.6 ± 87.1	57	1.00

performed by the respiratory therapists were most frequently performed and most commonly associated with the occurrence of lapses. These findings suggest that oxygen administration tasks either distracted from or interfered with cervical spine immobilization. Training to avoid this potential distraction and assignment of tasks such as cervical spine immobilization to team members not involved in airway and oxygenation management are appropriate strategies for reducing the number and duration of lapses related to this class of tasks.

Lapses may occur when a collar is being removed to examine the cervical spine, when a collar placed at the scene is exchanged for a more appropriately fitting collar or when the medical team temporarily removes all or part of the collar in an attempt to clinically examine the cervical spine. Although performing these maneuvers requires stabilization of the neck in coordination with other team members, we observed that cervical collar manipulation increased the likelihood of and number of lapses. Because most team members are aware of the need to stabilize the cervical spine during these manipulations, the occurrence of lapses in this setting suggests that team members may be unaware that these lapses are occurring or are unable to prevent them. Video analysis of the workflow associated with collar manipulation is needed to identify strategies to better coordinate these procedures.

This study has several limitations. First, determination of a lapse was based on a review of videos recorded from ceiling-mounted cameras. Additional lapses may have been missed if the camera view of the patient was obstructed. Second, most tasks performed around the head and neck were not associated with the occurrence of a lapse. Because of sample size, this study may have been underpowered to show the impact of some of these tasks, such as intubation. Third, although we have identified factors associated with lapses, we were unable to directly identify whether lapses were related to a lack of training, distraction, challenges related to coordinating tasks within a constrained area or a combination of these factors. Additional insight into causation may be obtained by interviewing the team members involved in the occurrence of a lapse. It is possible that many team members may be unaware of the occurrence or duration of lapses when distributed throughout the event and when related to coordinated tasks performed by several team members. Fourth, because no patient sustained a severe cervical injury, we could not define an amount of acceptable movement of the cervical spine in patients with unstable injuries. Finally, this study was a retrospective review at a single institution. Our findings may represent institution-specific practices and role assignments during trauma evaluation that may not be generalizable to other trauma centers.

Patients with an unstable cervical spine injury after blunt trauma are at potential risk for damage to their spinal cord from cervical motion. To prevent cervical spinal cord injury, it is current practice to manually immobilize or place a properly fitted cervical collar until a cervical injury can be ruled out. When manual immobilization of a patient's cervical spine is performed, the team leader should ensure the team member immobilizing the neck is using proper technique to minimize adverse events such as pain and skin breakdown. Team

members involved in the care of trauma patients should be aware that errors in maintaining a neutral neck position for the patient are likely to occur while performing activities centered around the patient's head and neck, particularly when placing supplemental oxygen on the patient or when placing a cervical collar. During the performance of these tasks, team leaders need to coordinate care among team members to prevent lapses from occurring. Team leaders should determine the need for continued cervical spine immobilization based on an assessment of risk for a cervical injury and clinical examination to maximize its benefit and to minimize any potential harm from its use.

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Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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