The Effect of Rigid Cervical Collars on Internal Jugular Vein Dimensions

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Abstract

Objectives: Prior research has demonstrated that rigid cervical collars cause an increase in intracranial pressure (ICP). The mechanism for this effect is unclear and one proposed mechanism involves obstruction of venous outflow in the neck. Ultrasound (US) allows assessment of internal jugular vein dimensions and may yield information regarding the mechanism for the increase in ICP seen with rigid collar application.

Methods: Forty-two healthy volunteers underwent US examination of the internal jugular vein before and after cervical collar application. Internal jugular vein cross-sectional areas were compared with and without the cervical collar in place.

Results: The cross-sectional area of the internal jugular vein increased significantly ($p < 0.0001$) after application of the cervical collar. The mean percentage increase in cross-sectional area was 37% (95% confidence interval [CI] = 20% to 53%).

Conclusions: Internal jugular vein cross-sectional area increases after application of a rigid cervical collar. This supports the hypothesis that venous obstruction in the neck may contribute to the increase in ICP seen after rigid collar application.

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Spine immobilization with a rigid cervical collar is a critical component of the initial management of the blunt trauma victim, as cervical spine injuries have been reported in 3.5% to 6% of patients sustaining severe head injury.[1,2] Recent studies have suggested a potential detrimental effect of cervical collars on patients with severe head injury by demonstrating that cervical collars can elevate intracranial pressure (ICP).[3–8] Increased ICP decreases cerebral perfusion and exacerbates ischemia, thus increasing the likelihood of secondary brain injury.

Although the relationship between rigid cervical collars and ICP has been investigated in multiple studies, the exact mechanism by which this occurs has not been elucidated. Some authors have proposed that venous compression in the neck may lead to increased jugular venous pressure and, secondarily, increased cerebrovenous and ICPs.[8]

Prior work on this subject used invasive monitoring of intracranial and cerebral perfusion pressures in patients with traumatic brain injury. Using changes in internal jugular vein dimensions as a surrogate marker for changes in internal jugular venous pressure, we used ultrasound (US) to noninvasively assess the size of the right internal jugular vein after application of a rigid cervical collar in healthy volunteers. We postulated that there would be a significant increase in jugular venous size after collar placement, potentially yielding further insight into the mechanism responsible for the elevation of ICP associated with rigid cervical collars.

METHODS

Study Design

This was a prospective study in healthy volunteers, all of whom were resident physicians, medical students, and nurses in our ED. Participants received no remuneration for their involvement. The institutional review board at SUNY Downstate/Kings County Hospital Center approved the study protocol.

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Study Setting and Population

Forty-two healthy adult volunteers were enrolled at an urban Level 1 trauma center with emergency medicine and emergency medicine/internal medicine residency programs. Only measurements of the internal jugular vein were obtained; no physical characteristics of the volunteers were documented.

Study Protocol

Internal jugular vein measurements before and after cervical collar application were obtained in five healthy adult volunteers to determine sample size. In these volunteers, the mean (±SD) cross-sectional area of the right internal jugular vein was 0.61 (±0.22) cm^2 before c-collar placement and 0.81 (±0.39) cm^2 after placement. Using the results of this pilot data, to achieve a power of 0.80 (two-sided, $\alpha = 0.05$), we required 42 subjects in the study.

With subjects supine, the cross-sectional area of the right internal jugular vein was measured using an 8–5 MHz curvilinear array transducer (Sonosite MTurbo, Bothell, WA). This microconvex transducer was chosen for its small footprint and ability to obtain images through the anterior window of the cervical collar. Investigators were instructed to use the smallest amount of pressure necessary to obtain adequate transducer contact and image acquisition. Measurements were taken at the level of the laryngeal prominence of the thyroid cartilage. This site was chosen because it is an easily palpated landmark where exams can be reproduced at the same cranial–caudal level. A second measurement at the same site was taken immediately after the application of the Ambu Perfit ACE adjustable extrication collar (Ambu Inc., Glen Burnie, MD). This rigid cervical collar allows for adjustment based on body habitus, and collars were adjusted to obtain full cervical immobilization while minimizing discomfort to subjects. Given the normal variation in jugular venous size over the respiratory cycle, maximum (end-expiratory) dimensions were recorded during quiet passive respiration using the cine-loop function. Investigators used the machine's built-in ellipse measurement function, and cross-sectional areas were calculated automatically. Two of the investigators (MBS and CMT) performed all of the exams independently and recorded digital still images for subsequent review by a US fellowship-trained physician who was instructed in internal jugular vein measurement, but blinded to the objectives of the study.

Data Analysis

Jugular venous dimensions before and after application of the rigid cervical collar were analyzed using a paired Student's t-test. Blinded independent measurements of unlabeled digital images by a US fellowship-trained emergency physician were performed. A Bland-Altman analysis was conducted to assess agreement between investigator's measurements and the blinded reviewer's measurements. The Bland-Altman plot was generated using GraphPad Prism 5 (GraphPad Software, Inc., La Jolla, CA).

RESULTS

There were 42 subjects enrolled: 52% were male, and the mean age of subjects was 27 years (range = 19–50 years). The mean (±SD) cross-sectional area of the right internal jugular vein was 0.70 (±0.28) cm^2 without the rigid cervical collar and 0.89 (±0.35) cm^2 after placement of the collar: the cross-sectional area of the internal jugular vein increased significantly ($p < 0.0001$) after application of the cervical collar. The mean percentage increase in cross-sectional area was 37% (95% confidence interval [CI] = 20% to 53%). Figure 1 contains a graph displaying the change in cross-sectional area after cervical collar application in each individual subject. The Bland-Altman analysis yielded a bias of −0.002 (95% CI = −0.06 to 0.06) and is presented in Figure 2.

DISCUSSION

Although multiple studies have demonstrated the effect of cervical collars on increased ICP, the mechanism for this effect remains unclear. One proposed mechanism

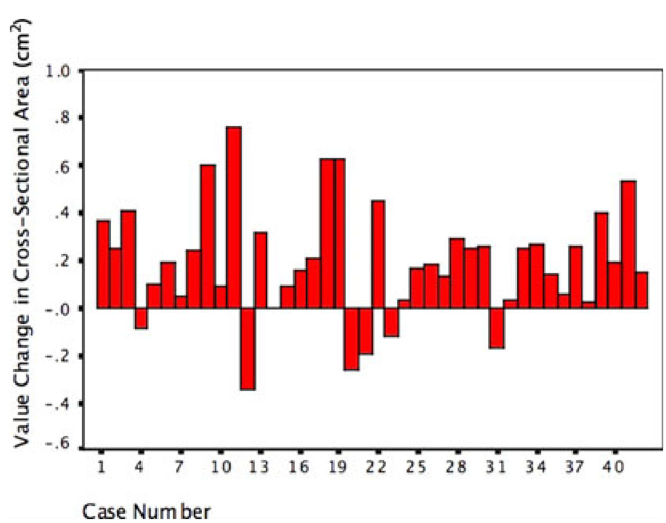

Figure 1. Change in cross-sectional area of the right internal jugular vein after cervical collar application, by subject. Positive values represent increases in internal jugular vein size after collar application; negative values represent decreases in size after collar application.

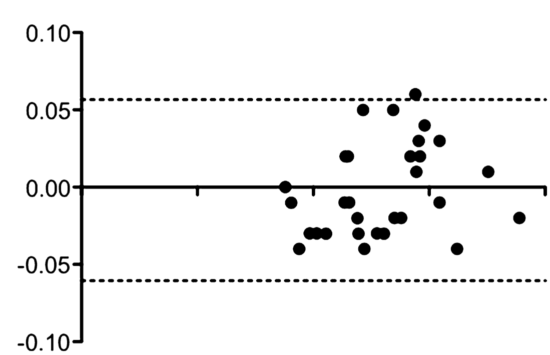

Figure 2. Bland-Altman plot of interobserver agreement—generated using GraphPad Prism 5.

involves nociceptive stimulation from the discomfort of the collar. Studies that have examined this possibility have not found a causal relationship; there were no associated changes in mean arterial blood pressure or heart rate after collar application, and the elevation of ICP was also found in well-sedated patients in whom a nociceptive response would not be expected.[3–5]

Another explanation for the elevation of ICP seen with cervical collars is that the collars disrupt venous outflow. Intracranial venous drainage may be hindered by an increase in internal jugular pressure due to the collar's direct compression of the jugular veins or by some other mechanism. Ferguson et al.[6] recorded mean interface pressures ranging from 0.3 to 9.1 mm Hg directly underneath cervical collars, and the values varied depending on the collar that was used. Kuhnigk et al.[4] also found variations in the change in ICP depending on the collar used. These results suggest that a well-molded collar can minimize or potentially eliminate the increase in ICP.

In this study, we used US to examine the effect of collar application on right internal jugular vein size. Given the high compliance of the jugular vein, changes in venous pressure should result in an increase in vein dimensions. The results show a significant increase in cross-sectional area of the right internal jugular vein after collar application. The mean increase at the laryngeal prominence is 37%, supporting the theory that collars increase ICP via a mechanical effect on venous outflow from the brain. Moreover, the data suggest that if the increase in cross-sectional area is due to external compression of the cervical collar on the jugular veins, this compression occurs below the level of the laryngeal prominence.

LIMITATIONS

A single manufacturer's cervical collar was used for all subjects. The type of collar used may influence the change in ICP, and it is possible that a different type of rigid cervical collar could also result in a different effect on internal jugular vein dimensions. There was no standardization of cervical collar application other than subject comfort. There were no measurements of subject's blood pressures or other markers of intravascular volume, although these were healthy volunteers in whom there was no reason to suspect volume depletion.

Additionally, measurements were taken immediately after cervical collar application. It is possible that the changes in internal jugular vein dimensions may equilibrate with time. During our initial sample size calculation in five healthy subjects, measurements were taken before collar application, immediately after application, and 10 minutes after collar application. The measurements after application and 10 minutes later were identical. Given the discomfort of prolonged application of the rigid cervical collar, and the lack of an obvious effect on internal jugular vein dimensions (compared to those obtained immediately after collar application), we elected to eliminate the delayed measurement from this study. However, because we did not formally investigate the effect of prolonged collar application, the possibility exists that vein dimensions may change over time. We did not record the body mass index or neck measurements of our subjects, and it is possible that changes in jugular venous size after cervical collar application may differ in patients with different body mass indices or neck sizes.

Because this was a study of healthy volunteers, we did not monitor subjects' ICP before and after collar application and thus are unable to prove that changes in internal jugular vein size are responsible for the increase in ICP seen with rigid cervical collar application. Subsequent research on this topic should focus on a population of patients in whom invasive or noninvasive ICP monitoring is feasible.

CONCLUSIONS

In healthy volunteers, internal jugular vein cross-sectional area increases after application of a rigid cervical collar. This may provide a possible explanation for the increase in intracranial pressure seen with rigid cervical collar use in victims of head trauma. Ultrasound provides a noninvasive means to measure jugular venous dimensions, and by using the surrogate measurement of jugular vein cross-sectional area, ultrasound may facilitate identification of a cervical collar design that minimizes the potential deleterious effects on intracranial pressure.

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