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Jugular Vein Compression Collars for Mitigating Traumatic Brain Injuries in High-Impact Activities: A Narrative Review

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Abstract

The "Q-Collar" is a device designed to mitigate head injuries, particularly in scenarios such as contact sports and military operations where trauma to the head is a significant risk. It operates by exerting an external compressive force on the jugular veins, which effectively increases blood volume within the brain to counteract the "slosh" effect—that is, the movement of the brain within the skull during sudden impacts. The research documented in this literature review investigates the Q-Collar's efficacy by examining various clinical studies, as well as animal models, to understand its role and proven effects on reducing head trauma. This review includes 21 studies that were identified through a literature search using keywords related to "Jugular Vein Compression Collar" in the PUBMED database. The discussion highlights the physiological mechanism behind the Q-Collar's function: by compressing the jugular veins, it reduces the compliance of the cranial cavity, thereby stabilizing the brain and decreasing the risk of traumatic brain injury. The review finds evidence of the Q-Collar's effect in increasing intracranial and intraocular pressures, which suggests a mechanical countermeasure to the destabilizing effects of brain movement after an impact. Moreover, the findings include significant data from studies on high school athletes and special forces personnel, showing that Q-Collar users exhibited fewer microstructural brain alterations, better maintenance of cognitive functions, and fewer changes in white matter integrity than their non-collared counterparts. Preclinical small animal studies similarly present a reduction in inflammatory biomarkers associated with brain injury, indicating the collar's potential in protecting against histopathological changes. Research on the Q-Collar's use following blast exposure in military training shows additional benefits in memory function protection and auditory processing, as well as reduced auditory injury and tympanic membrane rupture, augmenting the case for the collar's protective effects. Finally, the review also touches on a potential application for patients with orthostatic hypotension, given the collar's influence on carotid baroreceptor-induced sympathetic activity. Hence, while the body of evidence under review supports the notion that the Q-Collar may be a valuable adjunct to helmets in the prevention of traumatic brain injuries, the review calls for further, longer-term studies to fully understand the extent of its benefits and potential limitations. The collective findings so far point towards a positive impact of the Q-Collar in scenarios of head trauma, with the device contributing to protective anatomical and functional changes within the brain. However, the nature of these studies—predominantly short-term and focusing on immediate or season-long effects—highlights the need for future research that extends beyond these temporal boundaries.

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1. Introduction

Traumatic brain injuries signify a major public health challenge, particularly in the United States, where estimates by the National Institute of Neurological Disorders and Stroke show that annually, between 1.6 to 3.8 million TBIs are associated with sports activities alone[1]. The gravity of this issue is amplified when considering military personnel, who are routinely subjected to the risk of brain injuries from blasts and other combat-related incidents. While protective headgear has undoubtedly reduced the risk of TBIs, there remains a need for supplemental protective strategies, as helmets are largely ineffective in preventing concussive injuries and long-term brain damage[2].

The limitations of traditional headgear have led to research into additional protective methods that can be used alongside helmets to further mitigate the risks of TBIs. One such innovative approach is the utilization of a jugular vein compression collar, commonly referred to as the Q-Collar. Designed to be worn around the neck, the Q-Collar exerts a compressive force on the jugular veins, leading to an increase in intracranial blood volume. The theory is that by increasing blood in the cranial cavity, the Q-Collar could reduce the "slosh" effect, a term which describes the motion of the brain within the skull when an impact occurs. This "sloshing" is thought to contribute to the severity of brain injuries, as it can cause strains and potentially damage brain tissue. The premise behind the development and use of the Q-Collar is grounded in the biomechanics of cranial contents during an impact. Traditional helmets have been adept at dispersing external forces and preventing skull fractures; however, they are limited in their capacity to mitigate the internal movements of the brain, which can lead to diffuse axonal injuries and other forms of traumatic damage at the cellular level. By exploring the concept of increased intracranial blood volume via external compression of the jugular veins, researchers hope to leverage physiological mechanisms to stabilize the brain and protect it from such injuries.

To assess the validity and effectiveness of the Q-Collar, a growing body of research has explored its potential both in lab-based animal studies and in human clinical trials. This research has covered a range of variables including structural brain changes, cognitive function, and long-term histopathological outcomes. Clinical studies often entail the use of advanced neuroimaging techniques, cognitive testing, and the measurement of intracranial pressure, while animal models focus on cellular markers of inflammation and post-traumatic histology. This review delves into the science behind the Q-Collar, which has emerged as a noteworthy preventive measure against traumatic brain injuries. The rationale for the Q-Collar's design is rooted in biomechanical and physiological strategies to protect the brain during high-impact events.

A growing body of evidence suggests that traditional helmets, while beneficial, do not fully prevent the brain from moving within the skull upon impact, and thus, do not sufficiently eliminate the risk of TBIs.[3] This has spurred innovation in supplemental protective equipment like the Q-Collar, which focuses on reducing brain "slosh" by applying external pressure to the jugular veins to potentially stabilize brain position during sudden movements. To validate its efficacy and safety, the Q-Collar has been subject to a range of investigations. These have included studies on the fundamental premise of reducing slosh, assessments of its impact on intracranial and cerebrospinal pressures, its effects on biomarkers of brain damage, and any potential cognitive benefits. Both human and animal studies have been part of this review, each contributing insights into the mechanisms and effectiveness of jugular vein compression techniques.

Furthermore, the Q-Collar's implications extend beyond contact sports and into the military realm, where it could offer protection against blast-induced TBIs—a prevalent and serious concern for service members. Thus, the intersection of sports medicine, military research, and neurological science serves as the backdrop for the literature review. By assembling and synthesizing findings across diverse study parameters, this literature review seeks to illuminate the holistic picture of jugular vein compression collar technology. The review presents data-driven perspectives on the Q-Collar's potential to augment existing protective measures and reduce the incidence and severity of TBIs. It underscores the necessity for continued investigation into long-term outcomes, adaptation strategies, and comprehensive understanding of physiological responses to ensure informed decisions regarding the implementation of the Q-Collar in various high-risk activities.

2. Methods

The approach taken to systematically review existing studies on jugular vein compression collars, with an emphasis on their application in reducing head injuries in sports and military scenarios, is detailed as follows. The goal of the review is to ensure a comprehensive and unbiased evaluation of the research topic. To capture a wide range of relevant articles, a structured literature search was conducted using the PUBMED database. A combination of keywords and phrases was employed, such as "Jugular Vein Compression Collar," "Q-Collar," "head injuries," "traumatic brain injuries," "sports," and "military blasts," along with Boolean operators to refine the search results. The aim was to include all relevant studies that investigated the effectiveness and implications of jugular vein compression technology in preventing or mitigating head injuries.

Studies were initially screened by title and abstract. Research articles were included if they directly discussed the use of jugular vein compression collars in the context of traumatic head injuries in humans or animal models and if they provided empirical data on outcomes such as intracranial pressure changes, biomarkers of brain injury, neuroimaging findings, or cognitive function assessments. Studies were excluded if they were not available in full-text format, if they did not specifically address jugular vein compression collars, or if they were reviews, commentaries, or opinion pieces without original data. Full-text studies that met the inclusion criteria were reviewed. Data were systematically extracted, including study design, sample size, participant demographics (for human studies), experimental protocols, type of jugular vein compression collar used, outcomes measured, and main findings. Any methodological variations, such as differences in the collar application or the assessment techniques, were noted to evaluate the consistency and comparability of the results across studies. The quality and validity of the included studies were examined using established criteria. This involved evaluating the study design (randomized controlled trials, case-control studies, cohort studies, etc.), control for potential confounding variables, and the adequacy of statistical analyses.

Given the potential heterogeneity of study designs and outcome measures, a narrative synthesis was conducted. The findings from various studies were compared and contrasted to identify patterns, consistencies, and discrepancies. Where possible, statistical measures of effect size and confidence intervals were collated to assess the magnitude of the Q-Collar's impact. This thorough methodology ensured that the literature review was based on a comprehensive collection of relevant studies that have robustly examined the use and effectiveness of the Q-Collar in reducing head injuries. The synthesis also sought to highlight any gaps in knowledge and to suggest areas for future research. Included studies encompassed a diverse population, especially targeting athletes in high-impact sports and military personnel, given their higher risk of TBIs. The review also included animal studies that provided valuable insights into the biological mechanisms and potential applications of the Q-Collar. Studies conducted in both real-world environments, such as sports fields and military training settings, and controlled laboratory conditions were examined to ensure a comprehensive understanding of the collar's effectiveness across different contexts. Qualitative data from the selected studies were examined to discern themes and key findings related to the use of the jugular vein compression collar. Quantitative data, including changes in biomarkers, neuroimaging results, and cognitive performance scores, were compiled and subjected to statistical analysis where appropriate. Meta-analytic techniques were considered, but the potential for methodological heterogeneity among studies necessitated a more descriptive synthesis approach.

We have applied a critical appraisal tool suitable for assessing the quality of both clinical and preclinical studies. This provided a systematic evaluation of biases, the rigor of experimental methods, the relevance of the study populations to the wider community at risk for TBIs, and the applicability of the study's findings. The review considered the ethical aspects of the included studies, particularly those involving human or animal subjects. It was noted whether the studies had obtained appropriate ethical approvals and if they were conducted in accordance with recognized ethical standards. While the review is of narrative nature, it adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for reporting systematic reviews and meta-analyses where applicable.[4] The adherence to these guidelines ensured the review's transparency, rigor, and replicability.

3. Summary of Literature

Jugular vein compression collars (**Image 1)** have been a topic of interest with regards to traumatic brain injuries. Trauma to the head results in pressure waves that ripple through the fluids of the skull, thus impacting local structures and causing neuronal disruptions. The phenomenon termed “slosh” refers to the destabilization resulting in a fluid wave as a partially filled container, i.e., the skull, is redirected with a force. Jugular vein compression collars provide compression to the jugular veins, resulting in increased intracranial blood volume and pressure, thus reducing the “slosh” effect by reducing compliance in the skull.[5] Optic nerve sheath diameter, a direct marker of intracranial pressure, was measured using ultrasound prior to and following application of a jugular vein compression collar. Significant elevations in diameter, indicating increased intracranial pressure, were found following application of the collar.[6] Intracranial pressure is further raised through elevations in cerebrospinal pressure in the skull following application of the jugular vein compression collar.[7]

Image 1: A depiction of a soccer player wearing a jugular vein compression collar on the neck, source: Ira L. Black/Getty Images

The severity of traumatic brain injuries can be characterized by local strain. Micro-damage to local tissue can be demonstrated through inflammatory biomarkers such as phosphorylated tau epitope AT8. Preclinical small animal studies indicate that a jugular vein compression collar results in a significant reduction in these inflammatory biomarkers following head trauma, thus indicating that jugular vein compression collars protect against histopathological changes related to head trauma.[8,9] Such studies have also demonstrated immediate increases in intraocular and intracranial pressure following application of the jugular vein compression collar.[10]

Due to the proposed reduction in micro-damage and histopathological changes to the brain following trauma, jugular vein compression collars have been investigated for their use in contact sports. Many prospective studies were conducted on high school football, soccer, and hockey players, dividing them into groups with collars and control groups without collars. These studies found significant reductions in microstructural brain alterations, improved working memory on standardized tasks, and reduced changes to white matter visualized through MRI in the athlete groups that wore the collar.[11-19]

The use of jugular vein compression collars have similarly been investigated for their use to mitigate brain injuries that occur following exposure to blasts. A trial analyzing special forces training groups exposed to blasts divided participants into collar vs. no collar groups. Prior to and following the training exercises, the participants had electroencephalography (EEG) tests. Participants who did not wear the collar were found to have longer periods of laminar electrocortical behavior, a finding associated with pathologies such as seizures.[19] In another trial, special forces were divided into collar and non-collar groups while exposed to blasts in simulation training. Using MRI findings prior to and following the training, it was found that the non-collar group had a significant amount of alteration in white matter.[21] A similar trial made use of fMRI brain activation to assess working memory following a training session with low impact blast simulations. The group without collars had a significant elevation in fMRI brain activation following the training when asked to perform a standardized task, while also indicating an increase in activity in the auditory region compared to the fMRI performed prior to the simulation training. The findings provide initial evidence for the protective effects of jugular vein compression collars on protecting memory functions after blast exposure with possible effects on auditory processing.[21] A study exploring jugular vein compression in rats exposed to otoacoustic emissions to simulate blast injuries provides further support for the role of jugular vein compression collars in ameliorating auditory injuries associated with blasts. In the study, rats were divided into collar and non-collar groups. Following exposure to otoacoustic emissions, the rats in the collar group had reduced auditory brainstem response threshold shifts in comparison to the control group. Additionally, the collar group was found to have a greater number of cochlear hair cells following blast injury.[23] A study with a similar design also found reduced cochlear hair cell loss and further concluded that the jugular vein compression collar significantly reduced tympanic membrane rupture.[24]

The use of the jugular vein compression collar also provides a degree of compression on the carotid artery. As such, it influences the baroreceptors in the carotid sinus, and induces an increase in sympathetic activity. This effect of the collar has been studied for its potential in patients with orthostatic hypotension, a condition in which there is a decrease in blood pressure as one assumes a standing position, as it could assist such patients in maintaining blood pressure with postural changes.[25]

4. Conclusion

In light of the comprehensive analysis of existing studies on the efficacy of the jugular vein compression collar, commonly referred to as the Q-Collar, the evidence substantiates its potential as a protective adjunct to traditional means of head injury prevention, such as helmets, in high-impact activities. This novel device leverages the physiological response of increasing intracranial blood volume by compressing the jugular veins, thereby mitigating the "slosh" effect—or the jarring brain movement— triggered by impact events. Collectively, the preclinical and clinical studies encompass a range of empirical data that demonstrate the collar's ability to act as a constraint, reducing the compliance of the brain within the skull and hence minimizing the risk of damage associated with traumatic brain injuries. Significant findings across diverse studies indicate that athletes wearing the Q-Collar show fewer microstructural brain alterations, better maintenance of cognitive functions, and fewer changes in white matter integrity compared to their non-collared counterparts. Particularly compelling are the results from trials involving high school sports athletes and military personnel, which suggest a protective effect of the collar in environments where the risk of concussive and sub-concussive head impacts is substantial. Furthermore, the evidence points to the potential benefits of the Q-Collar in scenarios of blast exposure, with preliminary studies revealing that collar use could preserve memory function and auditory processing, while also reducing injuries to auditory structures.

However, despite the promising data, it is imperative to acknowledge the need for continued research to fully explore the longer-term consequences of Q-Collar use. Most of the existing literature focuses on the short-term or seasonal effects of collar application, leaving the potential long-term implications largely uninvestigated. The effect of sustained jugular vein compression on cerebrovascular health, venous drainage, and other physiological processes requires thorough analysis to rule out any adverse effects that might arise from chronic use. In addition to the extension of research timelines, future investigations should strive to include larger and more diverse populations, encompassing various age groups, sports, and activities to enhance the generalizability of findings. Methodological standardization across studies is also crucial for minimizing variability and enhancing the strength of conclusions drawn from comparative analyses.

In pursuit of an evaluation of the Q-Collar's long-term safety and effectiveness, the employment of more sophisticated analytical methods, such as predictive modeling through machine learning algorithms, could markedly enhance our understanding.[26] Such computational techniques can exploit intricate patterns within large datasets, including neuroimaging, cognitive testing scores, and biomarkers, to forecast the risks and benefits associated with prolonged use of the Q-Collar. Furthermore, machine learning can facilitate the development of personalized risk assessments that account for individual variability in physiological responses to jugular vein compression. By integrating this advanced model of data analysis, the guidelines for Q-Collar usage can be refined, potentially leading to optimized individualized protection strategies that are both effective and devoid of harmful long-term repercussions.

Moreover, it is imperative that we also investigate the ethical dimensions and the psychological impact of mandating the use of such devices, particularly in adolescent populations. We must ensure that the introduction of the Q-Collar does not inadvertently heighten the perception of safety to levels that encourage riskier behaviors, a phenomenon known as risk compensation.

Hence, the Q-Collar represents a pivotal innovation in the domain of TBI prevention, especially in high-risk sports and military activities. While the findings to date are encouraging, reinforcing the collar's role in mitigating head injuries, it is clear that the Q-Collar is not a standalone solution but rather a supplemental protection strategy.

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