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Research Paper

Safety of Vascular Neck Restraint applied by law enforcement officers

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1. Background

Law enforcement officers (LEOs) are sometimes faced with violent or combative subjects who must be taken into police custody. While the need for any use of force (UOF) is uncommon during police encounters, occurring in less than 1 in 120 criminal arrests, unarmed physical force is the most used option.[1] Among the physical force options, a technique that is utilized by some law enforcement agencies is Vascular Neck Restraint (VNR), also known as the carotid restraint technique, among other names. This technique applies pressure to the lateral neck vasculature and – if properly applied – may quickly produce either voluntary subject compliance or temporary unconsciousness.[2,3] This technique is derived from martial arts holds and is distinctly different from "choke holds" and other forms of neck compression or manipulation which can restrict breathing or injure airway structures. A properly performed VNR does not apply pressure to the anterior neck, airway or trachea, and does not impair respiration.

VNR use by law enforcement agencies is variable. While some agencies do not authorize its use, others have used it for many years and continue to do so. It is typically reserved for higher levels of subject resistance/violence (e.g. active resistance or threat of grievous bodily harm or death) due to a higher perceived risk of injury to the subject or officer. Recent criminology studies have estimated that 34% of local police departments and 37% of sheriff's offices studied authorize the use of VNR.[4,5] Actual use of VNR during subject apprehension is relatively rare with some estimates suggesting it is used in only 0.04–0.1% of UOF incidents.[6,7] In response to some high-profile incidents which may have involved neck compression or manipulation (though not application of VNR), the use of all neck holds by LEOs has been restricted or banned in many jurisdictions.[8]

The infrequent use of VNR limits systematic research into its safety. The medical literature contains several physiology studies related to VNR[9,10,11,12,13] as well as case reports of injuries and death after use of VNR or similar martial arts maneuvers.[14,15,16,17] Case series of police VNR use are rare, but a 2008 Canadian study of police UOF reported 17 VNR uses, with no fatalities or hospitalizations and one minor injury due to the technique.[18] A more recent 2021 report from a single law enforcement agency in Washington State reviewed 230 VNR uses over an eight year period.[19] This report documents an unusually high rate of VNR use in that agency (29% of all UOF incidents), and found no deaths due to the technique. They did find a lower incidence of subject injury when comparing VNR use to other UOF options. While this evidence is both reassuring and useful, there are still no large epidemiologic studies that provide robust evidence of the rate of death, significant injury, or other medical complications after VNR use by law enforcement. Thus, evidence-based recommendations for medical evaluations after use of VNR are lacking. In addition, the success rate of VNR application, defined as effectiveness in allowing successful apprehension of a resisting or combative subject, has not been reported.

We performed a multi-agency review of VNR applications by LEOs, both in field settings and in training, to determine the rate of medical complications after VNR use by police. This information can inform policy decisions by law enforcement agencies regarding training and field use of VNR techniques and allow for evidence-based recommendations for medical providers who assess patients after VNR application.

2. Methods

We performed a retrospective review of records from three North American law enforcement agencies that train officers in VNR

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application and have authorized its use as a force modality. Institutional review board approval was obtained in the US (Wake Forest University and the University of North Carolina) and Canada (Carleton University).

Each agency reviewed its UOF investigation records for up to an 11-year time period between 2010 and 2020 to determine the number and effectiveness of field VNR applications as well as any subject injuries sustained during apprehension. Law enforcement agencies typically conduct an internal review after each significant use of force event, including VNR application, to ensure compliance with applicable laws and agency protocols and to determine whether any injuries sustained by subjects are related to police actions. These investigations may include the review of officer reports, body camera footage, witness interviews, photo/video evidence, and in some cases, medical records. Access to medical records by United States law enforcement agencies is allowed under specific conditions by HIPAA regulations (45 CFR 160).[20] Access to medical records by Canadian law enforcement agencies is similarly restrictive.[21] Participating agencies confirmed that they have a medical screening process to identify illness or injuries in arrestees (US agencies), or assess for signs of illness or injury which can then prompt a medical exam (Canadian agency), and that each VNR application in the field is subject to an internal UOF review.

Each participating agency estimated the success rate of field VNR use (defined as effectiveness in allowing apprehension of a resisting or combative subject) on an annual basis. One agency also tracked and reported whether or not each subject was rendered unconscious due to VNR application.

Each participating agency also reviewed its training records over the same time period to determine the number of trainees and estimated training applications of VNR, as well as any injuries sustained. Agencies that authorize VNR use perform initial and ongoing refresher training, which includes each trainee both applying and receiving numerous VNR applications. This training was dichotomized into training that included application of VNR with full pressure application to the neck and potential loss of consciousness by trainees (typical of initial VNR training), and training that did not include full pressure to the neck (typical of annual in-service or refresher training). Of note, VNR application is not taught in isolation; the training typically also includes grappling, ground fighting, and cuffing techniques against active resistance that may also result in injuries. The number of trainees and estimated VNR applications were reported, but due to variability in training among agencies, only the number of trainees was used for analysis.

Reported injuries were reviewed by a board-certified Emergency Physician affiliated with each agency, who reviewed de-identified information and determined injury severity according to an *a priori* injury severity stratification scale (Table 1). This ranking of injuries was based on actual injuries diagnosed after medical evaluation, not on presenting symptoms. Injuries stratified as moderate or severe were grouped under the term "significant injuries." Usage data and de-identified case and injury reports were submitted to investigators using encrypted email and REDCap (Research Electronic Data Capture), a secure online data submission and management software hosted at Wake Forest University.[22] Injuries were classified into groups as being related to neck/face/head pressure and manipulation of the VNR itself, related to the physical struggle or grappling component that accompanies the use of VNR, or related to other factors such as another force modality or self-inflicted. Multiple injuries could be reported in a single subject; each injury was separately classified.

Data were exported and analyzed with descriptive statistics using commercially available spreadsheet software (Excel 2016, Microsoft Corporation, Redmond, Washington, USA). Observed proportions were calculated with 95% confidence intervals (CI) (or 97.5% CIs in the case of observed proportions of zero) using openly available statistics software (UCSF CTSI Sample Size Calculators/Confidence interval for a proportion [website]. https://www.sample-size.net/, accessed 4/24/2022).

Table 1
Injury severity stratification.

Injury Severity	Description	Examples
None	No formal Medical Evaluation[a], *and* No long-term disability expected	Soft tissue soreness, joint sprain/strain
Mild	Required Medical Evaluation, not admitted to hospital, *and* Mild or no long-term disability expected	Significant soreness, difficulty breathing, concern for fractures
Moderate	Admitted to hospital, *and/or* Moderate long-term disability expected	Neck or long bone fracture, concern for vascular or neurologic injury
Severe	Admitted to hospital, Severe long-term disability expected, and/or threat to life	Stroke, carotid dissection, ventricular dysrhythmias
Fatality	*Self-explanatory*	

[a] "Medical Evaluation" includes Emergency Department or Urgent Care visit acutely, or sub-acutely to a primary care provider or specialist.

3. Results

3.1. Participating agencies

Three law enforcement agencies participated in the study: a large local agency (San Diego Police Department), a statewide agency (North Carolina State Highway Patrol), and a federal agency (Royal Canadian Mounted Police), which, in contrast to many US federal agencies, also performs general policing service in many jurisdictions. Both participating US agencies authorized VNR at the level of active physical resistance, while the Canadian agency authorizes VNR at the level of threat of death or grievous bodily harm. Agency characteristics are shown in Table 2.

3.2. VNR uses

Participating agencies reviewed and submitted all field VNR applications and VNR training records for up to an 11-year period (range 5–11 years) between 2010 and 2020. A total of 944 field VNR applications were performed while apprehending combative or resistant subjects among the three agencies. An estimated 85,918 officers/trainees underwent initial and/or refresher training in VNR use. Among these, 14,083 trainees received at least one VNR application with full neck pressure as well as multiple partial pressure VNR applications, and 71,835 trainees received multiple partial pressure VNR applications.

3.3. Effectiveness and loss of consciousness in field applications of the VNR

The aggregate success rate of field application of the VNR (defined as effectiveness in allowing apprehension of a resisting or combative subject) was 92.6% (874/944) (95% CI 90.7–94.1%).

In the single agency that tracked whether or not each subject was rendered unconscious due to VNR application, 23.7% (82/346) of subjects were rendered unconscious with VNR use (95% CI 19.3–28.5%) while 76.3% (264/346) did not lose consciousness (95% CI 71.5–80.7%).

3.4. Fatalities and injuries in field applications of the VNR

There were no fatalities or significant (moderate or severe) injuries related to VNR after 944 field uses (97.5% CI 0.00–0.39%). Two fatalities did occur in subjects to whom VNR was applied. Autopsy reports and investigations showed that these deaths were due to cocaine toxicity and unrelated to the VNR.

Table 2
Characteristics of law enforcement agencies.

Agency	Type	Location	Sworn Officers	Total Employees	Square Miles	Population	Annual Calls for Service
1	Local	California	1843	2416	343	~1.4 million	~1.2 million
2	State	North Carolina	1800	3200	54,000	~12 million	~2 million
3	Federal	Canada	16,000	30,000	~4.6 million	~7.5 million	~2.8 million

There were 9 subjects with 12 reported injuries after 944 field applications of the VNR, a rate of 0.95% (95% CI 0.44–1.8%). All of these injuries were adjudicated as mild. One subject had neck soreness/swelling related to the VNR itself, while 7 injuries were related to grappling during apprehension and 4 injuries were related to canine deployment, conducted electrical weapon use, or were self-inflicted. These data are summarized in Table 3.

3.5. Training-related fatalities and injuries

Among the estimated 85,918 officers/trainees that underwent VNR training, there were no fatalities and no significant (moderate or severe) injuries (97.5% CI 0.00–0.00) identified. There were 76 injuries reported, a rate of 0.09% (95% CI 0.07–0.11). All reported injuries were mild. Most training injuries (47/76, 61.8%) were related to the grappling component of VNR training, while a minority (29/76, 38.2%) were due to the neck compression/head manipulation of VNR application. These VNR-related mild injuries included neck and shoulder soreness, sprain/strain, or swelling, dizziness or headache, and one case of hemotympanum. There were no cases of cervical fractures, vascular injuries or dissections, strokes, or other intracranial pathology identified. These data are also summarized in Table 3.

4. Discussion

The VNR technique is similar to many martial arts techniques as may be found in judo or jiu jitsu, formally known as shime-waza.[2,23] While no fatalities have been recorded since their introduction in jiu jitsu in 1882, there have been case reports of significant injuries including carotid dissection and stroke; death has been reported as well, albeit without definite causality.[14,15,17] In addition, there have been cases of in-custody deaths that have occurred after apparent neck manipulation maneuvers by police officers[16,23] and anecdotal reports of strokes after VNR training in police officers. While it is unclear if these complications are directly attributable to the use of a properly applied VNR or to other factors, these anecdotal reports are of considerable concern to police departments, health care providers who evaluate patients after VNR use, and the public. These concerns make injury epidemiology studies, such as this one, important to clarify medical risks and guide policy decisions.

While VNR-like maneuvers have been used in jiu jitsu and mixed martial arts for many years, literature reflecting their safety is scant. In one survey of 4307 combative sports/mixed martial arts athletes, 1443 (33.5%) of the respondents reported receiving over 500 applications over the course of their combative sports careers.[24] 3257 respondents (76%) reported experiencing near-loss of consciousness, while 1198 (28%) reported full loss of consciousness during these maneuvers. No significant injuries such as fractures, strokes, or vascular injuries were reported. Additionally, 83.6% of respondents responded that they thought VNR would be appropriate for use by LEOs as an alternative escalation of force option.

Table 3
Injuries and Fatalities after VNR use or training.

	Number	Subjects with Injuries			
		Mild	Moderate	Severe	Fatalities
Field VNR Applications	944	9 (0.95%)	0	0	0
VNR trainees	85,918	76 (0.09%)	0	0	0

Proper VNR training teaches application of various levels of pressure only until compliance is gained or the subject loses consciousness and can be taken into custody.[23,25] An early physiology study from 1943 detailed an experiment that utilized carotid occlusion for a much longer period, up to 100 s[26,27] In this study a group of 137 subjects, including prisoners and institutionalized psychiatric patients, were placed in an apparatus that compressed both carotid arteries to study the effects of acute cerebral anoxia. The researchers concluded that "Periods of acute arrest of cerebral circulation for as long as one hundred seconds appear to be well tolerated and are followed by rapid and uneventful recovery." While such studies could not be repeated today for ethical reasons, the lessons learned from it are pertinent to modern discussions of VNR. In this study, the mean time to unconsciousness was approximately 6–6.5 s. This is similar to more recent studies in resistive trained combative sports participants (mean 9 s).[28]

As mentioned previously, a 2021 report from a single police agency made a significant contribution to the sparse literature on VNR. This report reviewed 230 police uses of VNR against criminal subjects and found no fatalities related to the technique. They further found subject injury rates that were lower with VNR compared to other physical force options.[19] Our data add an additional 944 reported field uses of VNR without fatalities or significant injuries. In our study population there were no significant injuries or deaths after field VNR application by LEOs and the risk of minor injury was low. The large sample size of this study allows calculation of narrow confidence intervals for these observations. Combining our observations with the previous study, there have been no fatalities observed after 1174 LEO field uses of VNR reported in the medical literature (97.5% CI 0.00–0.03%) and these findings regarding death and injury are consistent across multiple agencies.

These findings do not exclude the possibility of a rare serious complication or guarantee safety if the technique is not applied correctly, but the likelihood of these events appears very low. Importantly, case reports have identified strokes and vascular injuries occurring after VNR or similar maneuvers in martial arts, often with delayed presentations.[14,15,17] We therefore recommend that clinicians treating a patient who develops severe pain or neurologic symptoms after VNR or other neck compression consider CT imaging of the head and neck and CT or MR angiography, even if the onset of symptoms is delayed.

Our study also provided us the opportunity to estimate for the first time the effectiveness of the VNR in facilitating apprehension and arrest of a resisting or combative subject by LEOs. The 92.6% effectiveness rate seen demonstrates that this is a highly effective technique. Notably, only about one quarter of uses resulted in loss of consciousness in the subject, demonstrating that the VNR is an effective control and grappling technique independent of producing unconsciousness.

There have been recent calls to ban all neck manipulation techniques by LEOs due to safety concerns. The absence of fatalities or significant injuries demonstrated by our data, combined with a high success rate and lower overall subject injury rate compared to other force options reported in another recent study,[19] suggest that these bans may be unnecessary when the VNR technique is executed by well-trained LEOs. Further, banning a safe and effective force option may be counterproductive, by forcing LEOs to utilize other force options with higher risks of injury.

A recent review of strangulation injuries addressed LEO use of VNR

saying "Although there is little debate regarding the dangers of intentional anterior airway compression chokes, VNR remains understudied and a potentially viable option when looking at comparative use of force options."[29] Our study directly addresses this need for additional study of the safety of VNR.

5. Limitations

All retrospective studies suffer from potential limitations due to missed injuries or recording errors. In this study reviews were conducted internally by each participating department, with likely variable thoroughness of data gathering potentially affecting detection and reporting of some injuries. Significant injuries or deaths being missed is thought to be unlikely due to the mandatory nature of police UOF investigations and annual reporting requirements, as well as the high-profile nature of fatalities or significant injuries resulting from police UOF in North America. The number of trainees in each agency was estimated on an annual basis, giving an approximate but not exact number. This is a minor limitation in the context of the large number of trainees. Each agency also estimated the number of VNR applications each trainee applied and received during training (up to 75). This was thought to represent an overestimate of the number of VNR applications that applied significant pressure and might produce injury; therefore, the number of trainees was used instead of the estimated number of VNR applications.

6. Conclusions

In this study VNR performed by trained LEOs was both safe and effective. Our data revealed no fatalities or significant injuries, and analysis suggests that the risk of these is not higher than 0.4%. The real-world effectiveness of the VNR technique in allowing apprehension and arrest is estimated to be 92.6%, demonstrating its value in high risk police encounters. These results may be useful in informing law enforcement agency policies relating to use of the VNR.

Author contributions

WPB, GMV, and CH conceived and designed the trial, supervised the conduct of the trial, and undertook recruitment of participating centers. BH and JPS provided statistical advice on study design. WPB, GMV, CH, and DLM supervised data collection. WPB and CH led and all authors participated in data analysis. WPB drafted the manuscript, and all authors contributed substantially to its revision. WPB takes responsibility for the paper as a whole.

Declaration of competing interest

None.

References

1. Bozeman WP, Stopyra JP, Klinger DA, et al. Injuries associated with police use of force. *J Trauma Acute Care Surg*. 2018 Mar;84(3):466–472.
2. Vilke G. Neck holds (chapter). In: Ross DL, Chan TC, eds. *Sudden Deaths in Custody*. Humana Press; 2006.
3. Holman M, Vilke GM. Neck holds (chapter). In: Ross DL, Vilke GM, eds. *Guidelines for Investigating Officer-Involved Shootings, Arrest-Related Deaths and Deaths in Custody*. New York and London: Routledge; 2017.
4. Brooks C. *Local Police Departments: Policies and Procedures*. Bureau of Justice Statistics; 2020, 2016.
5. Davis E. *Sheriffs' Offices: Policies and Procedures*. Bureau of Justice Statistics; 2020, 2016.
6. Mesloh C, Henych M, Wolf R. *Less Lethal Weapon Effectiveness, Use of Force, and Suspect & Officer Injuries: A Five-Year Analysis*. Final Report to the National Institute of Justice. National Institute of Justice; 2008.
7. Kaminski R, DiGiovanni C, Downs R. The use of force between the police and persons with impaired judgment. *Police Q*. 2004;7(3):311–338. https://doi.org/10.1177/1098611103253456.
8. Palmer E. More than a dozen police departments have banned neck holds since george floyd's death—Minneapolis police hasn't. Newsweek. 6/4/2020. www.newsweek.com/minneapolis-police-ban-neckhold-restraint-george-floyd-1508626. Accessed April 2, 2022.
9. Mitchell JR, Roach DE, Tyberg JV, Belenkie I, Sheldon RS. Mechanism of loss of consciousness during vascular neck restraint. *J Appl Physiol*. 1985;112(3):396–402, 2012 Feb.
10. Reay DT, Holloway Jr GA. Changes in carotid blood flow produced by neck compression. *Am J Forensic Med Pathol*. 1982 Sep;3(3):199–202.
11. Stellpflug SJ, Menton TR, Corry JJ, Schneir AB. There is more to the mechanism of unconsciousness from vascular neck restraint than simply carotid compression. *Int J Neurosci*. 2020 Jan;130(1):103–106.
12. Denk W, Helmer M, Missliwetz J. Blood flow in carotid and vertebral arteries at "choke holds" in ultrasound Doppler. *Z Rechtsmed*. 1990;103:369–377.
13. Rau R, Raschka C, Brunner K, Banzer W. Spectral analysis of electroencephalography changes after choking in judo (juji-jime). *Med Sci Sports Exerc*. 1998 Sep;30(9):1356–1362.
14. Kato Y, Hayashi T, Tanahashi N, Takao M. Carotid artery occlusion caused by the judo chokehold technique, 'shime-waza. *Intern Med*. 2017;56(7):881–882.
15. Powell T, Fullam T, Hammett J, Nettlow D, Harris J. Vertebral artery dissection in active-duty soldier due to mixed martial arts choke hold. *Fed Pract*. 2018 Jul;35(7):12–17.
16. Reay DT, Eisele JW. Law enforcement neck holds. *Am J Forensic Med Pathol*. 1986;7(2):177.
17. Stellpflug SJ, Dummer MF, Martin CD, Vera JA, LeFevere RC. Cervical artery dissections and ischemic strokes associated with vascular neck compression techniques (sportive chokes). *J Emerg Med*. 2022 Jul;63(1):49–57.
18. Butler C, Hall C. Police/public interaction: arrests, use of force by police, and resulting injuries to subjects and officers – a description of risk in one Major Canadian city. *Law Enf Exec Forum*. 2008;8(6):141–157.
19. Hickman MJ, Scales RM, Strote JM, Worrall JL. Use of vascular neck restraints in law enforcement: a case-study of Spokane, WA. *Police Pract Res*. 2021;22(6):1668–1678. https://doi.org/10.1080/15614263.2021.1948849.
20. Bozeman WP, Stopyra JP, Corn P, Moser JT. Protected health information and use-of-force investigations. *FBI Law Enforc Bull*. 2018;87(4).
21. Canadian Medical Protective Association. Physician interactions with police. Publication P1101-3-E, November 2019. https://www.cmpa-acpm.ca/en/advice-publications/browse-articles/2011/physician-interactions-with-police. Accessed April 25, 2022.
22. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) - a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inf*. 2009 Apr;42(2):377–381.
23. Koiwai EK. Deaths allegedly caused by the use of "choke holds" (shime-waza). *J Forensic Sci*. 1987 Mar;32(2):419–432.
24. Stellpflug SJ, Schindler BR, Corry JJ, Menton TR, LeFevere RC. The safety of sportive chokes: a cross-sectional survey-based study. *Phys Sportsmed*. 2020 Nov;48(4):473–479.
25. Personal Communication. Robert Bragg, Director of Training, National Law Enforcement Training Center 4/19/2022.
26. Rossen R, Kabat H, Anderson JP. Acute arrest of cerebral circulation in man. *Arch Neurol Psychiatr*. 1943;50(5):510–528.
27. Smith BA, Clayton EW, Robertson D. Experimental arrest of cerebral blood flow in human subjects: the red wing studies revisited. *Perspect Biol Med*. 2011;54(2):121–131.
28. Stellpflug SJ, Menton WH, Dummer MF, Menton TR, Corry JJ, LeFevere RC. Time to unconsciousness from sportive chokes in fully resisting highly trained combatants. *Int J Perform Anal Sport*. 2020;20(4):720–728.
29. Stellpflug SJ, Weber W, Dietrich A, et al. Approach considerations for the management of strangulation in the emergency department. *J Am Coll Emerg Physicians Open*. 2022 Apr 16;3(2), e12711.