Neurosurgical Forum
LETTERS TO THE EDITOR**Air-gun pellet injuries to the head and neck: what are the mechanisms of injury and optimal steps in management?**

TO THE EDITOR: We read with interest the article by Kumar et al.³ (Kumar R, Kumar R, Mallory GW, et al: Penetrating head injuries in children due to BB and pellet guns: a poorly recognized public health risk. *J Neurosurg Pediatr* 17:215–221, February 2016). The authors retrospectively collected the data of 14 victims of what they called air-gun pellet injuries who were referred to 3 different centers. They highlighted their findings in Table 2 of their manuscript. Their review of the muzzle velocity performance is very informative for readers of the neurosurgical literature who are interested in the field of penetrating head injuries.

Interestingly enough, our group published a collection of 16 pediatric cases injured by 0.177-caliber lead pellets with a diabolo-style shape in 1997.¹ The summary of our findings is reproduced from that communication and added as a table in this letter to show that our results were rather similar to those of Kumar et al., although with some important differences. We would like to highlight some of them and also comment on some other issues as well.

1) The entrance points of the pellets into the skull are mentioned by the authors, but the weak roof of the orbit as the main avenue of entrance to the cranium for these low-velocity pellets should be better emphasized. The point is that the rifles or guns shooting these kinds of missiles are not engineered in standard industries and do not hold for example International Organization for Standardization numbers in every aspect. These guns and projectiles are produced by home-made manufacturers, lack advanced compressed gas technology (which means that the pellets are shot at different velocities), and are distributed by local sellers among the youngsters. So, the speed of pellets is nearly always less than the amount mentioned in Kumar et al.³ The skull entry site in the Kumar et al. series was frontal in 8 patients (57%), temporal in 2 (14%), orbital in only 3

(21%), and parietal in 1 (7%). The injury types overlapped among many patients, and some of them were not driven into the skull. Injuries included subarachnoid hemorrhage in 7 patients (50%), depressed skull fracture in 4 (29%), parenchymal contusion in 4 (29%), cerebral edema in 3 (21%), intraparenchymal hemorrhage in 2 (21%), subdural hematoma in 1 (7%), intraventricular hemorrhage in 1 (7%), and pseudoaneurysm formation in 1 (7%). Among them, 10 of the 14 patients required an operative intervention. This is quite different from our findings (Table 1), with the entrance through the orbit in 11/16 (69% orbital entrances). It shows that such missiles cannot easily penetrate through the skull bone, and need special circumstances to happen accidentally between the offender and the victim.

2) Considering passage of the missile through the skull base region in most of the cases, the shell often can be stopped in and around the sella. Damage to the cavernous sinus and its neurovascular structures was predictable, and we insist on some kind of vascular study in nearly all similar cases. We encountered both traumatic aneurysm and carotid cavernous fistula in our series (Table 1).

3) Even though it might not seem necessary to remove the BB pellets in all cases, because of the higher chance of development of late infection in these penetrating injuries (Table 1) in contrast to high-velocity war injuries,² we deem early and complete debridement a mandatory procedure.

4) Advising the use of helmets for children playing with BB guns can be a good suggestion on the part of pediatric neurosurgeons, although it is of benefit only for the shooter and helmet manufacturer (because children who were not shooting BB guns wouldn't be wearing a helmet). Considering that these events are accidental and not preplanned, the use of helmets cannot possibly prevent all injuries to the victim.

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TABLE 1. Characteristics, treatment, and outcome in 16 patients with pellet gun wounds

Case No.	Age (yrs)	Sex	Pellet Entrance	Lodged*	Imaging Studies	Complications & Treatment	Results
1	9	M	Front of neck	VA	Angio	Removed	Good
2	6	M	Occiput	Split	CT	Removed	Good
3	5	M	Rt temporal	Lt temporal	Angio	TA removed	Good
4	8	M	Lt orbit	Cone, orbit, & CS	CT & angio	CCF embolized iatrogenically	Good
5	11	M	Lt orbit	Medial temporal	CT & angio	AgP w/in the CS	Good
6	9	M	Rt orbit	Rt parietal	CT & angio	Brain abscess & AgP removed	Good
7	8	M	Lt orbit	Floor, anterior fossa	CT & angio	Removed	Good
8	15	M	Rt orbit	Rt temporal	CT & angio	Removed	Good
9	8	M	Rt orbit	Rt occipital	CT & angio	Removed	Good
10	10	M	Rt orbit	Rt parietal	CT & angio	Removed	Good
11	8	M	Rt orbit	3rd ventricle	CT & angio	Refused surgery	Good
12	11	M	Lt orbit	Floor, anterior fossa	CT & angio	Removed	Good
13	14	M	Rt orbit	Beside carotid artery	Angio	Removed	Good
14	10	M	Lt orbit	Frontal deep	CT & angio	Removed	Unknown
15	8	M	Lt temporal	Medial temporal	CT & angio	Removed	Unknown
16	9	M	Rt occipital	C-1, C-2 lamina juxta-VA	X-ray	Removed	Unknown

AgP = air-gun pellet; angio = angiography; CCF = carotid-cavernous sinus fistula; CS = cavernous sinus; TA = traumatic aneurysm; VA = vertebral artery.

* Last location of air-gun pellet.

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Disclosures

The authors report no conflict of interest.

Response

We appreciate the comments on our article and thank the writers for their additional insights.

We agree; the most vulnerable area on the face for projectile entry is the orbit, given the nature of the tissue. We encountered a plethora of orbital injuries due to nonpowder guns when reviewing the records, and yet, interestingly, only 3 of many included penetration of the intracranial compartment. This, indeed, is different from what was published by Amirjamshidi et al. in 1997.¹ Potentially, in addition to their suggestion regarding helmets, safety glasses should be recommended.

In our study, the most common site of injury was the frontal bone, which is a far more robust bone than those of the orbits. We theorized that the increased incidence of convexity bone penetration may be due to the increase in muzzle velocities of contemporary nonpowder guns. In

the letter Drs. Amirjamshidi and Abbassioun mention the inaccuracy of estimates of muzzle velocities. Indeed, there is some truth to this comment. Our calculations (based on the muzzle velocities reported by the manufacturers of popular air-powered guns) represent the worst-case scenario regarding projectile velocity and energy density at the point of skull penetration. Regardless of the calculations, 14 children presented with BBs or pellets in their brains. Certainly these rough calculations help to explain how a BB could penetrate the frontal bone, but they do not explain the gun safety failures that led to it being aimed in that direction in the first place. The main purpose of highlighting these calculations in our paper is to bring attention to the increased power and potential dangers of nonpowder guns. Perhaps this information could be used to facilitate a discussion on gun safety, when before these would be considered merely toys.

We also appreciate the authors' experience with these injuries and appreciate their recommendations. Because BBs and pellets lack the temporary cavitation in the traversed brain produced by larger firearms, they are thus generally less damaging to the neural tissue. However, BBs and pellets are still very capable of producing vascular injuries. We agree with the writers' recommendations, that there should be a low threshold for performing vascular studies after BB or pellet gun brain injury. In our opinion, the neurosurgeon should use his or her best judgment on whether debridement, decompression, or skull repair are necessary, and deeply lodged BBs or pellets should only be retrieved if they threaten imminent or ongoing neurological injury to the patient.

In the US, we live in an era of heightened sensitivity to any kind of gun regulation. Our authorship group includes

avid gun owners and those who have never fired a gun before. The regulation of nonpowder guns is done at the state level and is inconsistent. Although we take no stance on the regulation of nonpowder guns, we strongly recommend close parental or mature supervision of children using these weapons, which pose risks that are underappreciated.

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Thirty-day outcomes of cerebrospinal fluid shunt surgery: modeling using data from the National Surgical Quality Improvement Program–Pediatrics

TO THE EDITOR: We read with interest the article by Piatt¹ (Piatt JH Jr: Thirty-day outcomes of cerebrospinal fluid shunt surgery: data from the National Surgical Quality Improvement Program–Pediatrics. *J Neurosurg Pediatr* 14:179–183, August 2014). The literature suggests that up to 40% of shunts may fail within the 1st year of implantation in pediatric patients with hydrocephalus. There has been considerable effort to mitigate shunt failure with adjustable shunt valves, antibiotic-impregnated shunt tubing, and image-guided shunt insertions as well as many attempts to define variables that predispose a patient to shunt failure.³

Prospective studies of surgical outcomes are not always possible. When this is the case, large multicenter data registries, designed to analyze surgical outcomes, provide an alternative approach. The National Surgical Quality Improvement Program–Pediatrics (NSQIP-P) compiles data from patients who have had adverse events within 30 days of a procedure, from all of its participating centers.²

Piatt recently used the 2012 NSQIP-P database to identify clinical risk factors for shunt infection and failure, and to develop models for risk stratification.¹ This study identified the limitations of the NSQIP database because models constructed from this database accounted for no more than 6% of the observed variance. Inspired by Piatt's observations, we analyzed the 2013 and 2014 NSQIP-P

databases for ventriculoperitoneal shunt failure and shunt infection. Our conclusions are similar to those of Piatt: the variables in these databases are of limited value in constructing predictive models for shunt survival.

There were 4026 operative events in this analysis; 55 patients required reoperation because of infection and 512 patients had a reoperation for shunt dysfunction that was not due to infection. Logistic regression was used to create predictive models for reoperation. Using the variables in the NSQIP-P databases, models were only able to predict 2 of the 512 reoperations not related to infection; only 0.4% of actual events. Variables that were identified to be statistically significant predictors of reoperation included the following: 1) if patients had experienced weight loss prior to the surgery; 2) if they were receiving nutritional support; and 3) if they had had a proximal revision of their shunt at the surgery immediately prior to the reoperation.

Similarly, for patients who had an operation due to shunt infection, the model was only 14.5% accurate in predicting patients who would require reoperation for infection. Variables that predicted an increased risk of reoperation as a result of infection included 1) requiring a blood transfusion prior to surgery, and 2) being born prematurely.

For both of the end points we studied, the variables we found differ from those found by Piatt¹ and those reported from the Hydrocephalus Clinical Research Network.³ Our work and that of Piatt suggest that the factors that influence early shunt failure are not included in the NSQIP-P database. The current data elements are inadequate for the assessment of early (30-day) shunt outcomes. In planning future NSQIP pilots focused on shunt insertion and revision, other variables need to be considered and their relevance assessed prospectively. Additionally, the duration of follow-up should be lengthened so that the known times to failure are more adequately included.

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Disclosures

The authors report no conflict of interest.

Response

I am delighted to see these comments from Marguerie and Cochrane. They have analyzed 30-day reoperation rates after CSF shunt surgery in the NSQIP-P for 2013 and 2014, and they conclude that predictors available in the NSQIP-P data set cannot support a robust model of shunt failure in that time frame. They recommend expansion of the set of clinical data points and lengthening of follow-up for NSQIP-P surveillance of CSF shunt complications.

I note that the overall 30-day failure rate in the 2013–2014 data is 14.1%. The 30-day failure rates are remarkably tightly clustered in reports from different times and places: 13.5% in my analysis of the 2012 NSQIP-P data, 12.9% in a recent report from a consortium in the United Kingdom and Ireland, and 14% and 16% from the 2 prospective randomized shunt trials conducted in the 1990s.^{1,4,5} Taken together, these reports establish a fairly compelling quality benchmark. Marguerie and Cochrane confirm my impression that this benchmark is impervious to risk adjustment, the only consistent predictor being whether and what kind of shunt surgery precedes the index case. What remains to be determined about 30-day failure as a quality metric is whether important variation exists among surgeons or among institutions.

I cannot pass up this opportunity to acknowledge Dr. Cochrane's past work on outcomes variation in CSF shunt surgery.^{2,3} Working with data from Canadian provincial health plans, Cochrane and Kestle showed that infection rates were higher among surgeons with less than 5 years of experience. The mean 12-month failure rates were not associated with experience, but the variance of failure rates among surgeons with less than 5 years of experience was much higher than among surgeons with more experience.² I know of no other measurement of variance among surgeons in any quality metric in the management of hydrocephalus. These 2 investigators showed that surgeon experience was associated with infection and shunt survival as quantified by past case volume as well.³

As Marguerie and Cochrane suggest, the NSQIP-P will

be focusing more intently on CSF shunt surgery (Charles Vinocur, personal communication, 2016). In the future, cases will be evaluated at 90 days instead of 30 days, and eventually a participating institution will be able to compare its 90-day reoperation rate with the rates of other institutions participating in the NSQIP-P, just as comparisons of rates of surgical site infections and catheter-associated bladder infections can be performed now. The measurement of quality in the care of children with hydrocephalus is slowly coming into focus.

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