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Clinical Research

Higher Prevalence of Bovine Aortic Arch Configuration in Patients Undergoing Blunt Isthmic Aortic Trauma Repair

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Background: The prevalence of a bovine aortic arch configuration is higher in patients treated for thoracic aortic aneurysms and type B dissection; its prevalence in aortic isthmic trauma has not been described.

Methods: A case control study was performed comparing consecutive patients treated at our institution for acute isthmic aortic transection after blunt trauma between 2002 and 2019 and a control group of consecutive sex-matched individuals undergoing imaging for nonaortic disease. Imaging and clinical findings were reviewed. Subjects were divided into bovine and nonbovine groups and prevalence was compared. The length of the aortic segment between the left subclavian artery (LSA) and the next proximal great vessel was measured in the control population and a comparison was performed between bovine and nonbovine aortic arch subjects.

Results: Thirty-three consecutive (30 male) patients were reviewed, 66 individuals (60 male) were included in the control group. A higher incidence of bovine arch in trauma patients was found: 57.6% vs. 34.8% ($P = 0.007$). The median (range, mm) and mean (SD) distance between the bovine trunk and the LSA were 13 mm (2−27) and 12.4 mm (5.9), respectively, compared with 5 mm (1−27) and 7.8 mm (6.1) between the left common carotid and LSA in nonbovine aortic arches ($P < 0.005$).

Conclusion: A higher incidence of bovine arch in patients reaching out for surgical treatment for traumatic isthmic aortic transection was found in our population. Clinical interpretation of this finding can lead to several alternatives. Confirmation with larger series and data on prevalence of this anatomic variation in nonsurvivors is needed to provide a better understanding of this finding.

INTRODUCTION

Aortic trauma after a high-energy accident is a lethal condition; most patients die before arrival to a medical facility.[1−3] The mechanism of aortic rupture has been related to acute deceleration with forward movement of the mobile aortic arch against the rather stable descending aorta, fixed by the intercostal arteries to the spine. The tear is usually located at the isthmic region: the transition area between the mobile and fixed areas of the aorta, where the *ligamentum arteriosum* is located.

A bovine arch is the most common anatomic variation of the aortic arch.[4] It is defined as a common

Conflict of interest statement: none.
Funding: This research did not receive funding.

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Ann Vasc Surg 2019; ■: 1–4
https://doi.org/10.1016/j.avsg.2019.10.080

Manuscript received: September 18, 2019; manuscript accepted: October 20, 2019; published online: ■ ■ ■

origin of the brachiocephalic trunk (BCT) and the left common carotid (LCC) artery. It has been considered a misnomer, since the actual bovine arch found in cattle and other domestic animals like goats and sheep is a single aortic trunk from which all four great vessels originate[5] and common to other animals with deep chests, where a long distance between the aortic arch and the thoracic inlet would explain the presence of a single great vessel.

During development, the truncus arteriosus that later forms the aortic sac receives six pairs of branchial arches; these undergo selective apoptosis and the remaining vessels constitute the aortic arch, its great vessels and the pulmonary arteries. The aortic sac divides normally into two horns, the right will form the BCT and the left the LCC; if the aortic sac fails to divide, the LCC will not separate from the BCT forming a bovine arch. It is also important to understand that the segment of aortic arch between the LCC and the LSA artery has a different embryological origin than the more proximal and distal arch.

It has not been reported if this anatomical variation plays a role in aortic blunt trauma.

We report the prevalence of bovine aortic arch in patients undergoing blunt aortic trauma repair and a sex-matched Chilean population; in order to provide an objective aortic anatomic difference between groups; we compared the length of the segment of aorta between the LSA and the next proximal great vessel for bovine aortic arch subjects and the more common three-vessel arch.

MATERIAL AND METHODS

A case control study of all patients treated for acute isthmic blunt aortic trauma at our institution between 2002 and 2019 was performed. Pre and postoperative contrasted computed tomography imaging in arterial phase (CTA) were reviewed by two observers. Bovine aortic arch was defined as a common aortic origin of the BCT and LCC, both variants were included: (1)the BCT and LCC arise from the aorta as a common trunk with the division between both vessels located above the aortic arch greater curvature, and (2) the LCC originates from the BCT (Fig. 1). Incidence was calculated and compared with a sex-matched control group of individuals undergoing CTA at our institution ordered for nonaortic disorders, mostly to rule out pulmonary embolism. Individuals were excluded if an asymptomatic aortic aneurysm or dissection was found. There is no other report of the prevalence of this anatomic variation in Chile for comparison.

In the control group, the distance between the proximal edge of the origin of the LSA and the distal edge of the bovine trunk or the LCC, for the three-vessel arch anatomy, was performed using Horos ® software (Horosproject.org, MD). The linear distance between vessels at the greater curvature of the arch was used. These measurements were not performed in the trauma group due to anatomic distortion caused by the transection.

Descriptive statistics, chi-square, Mann-Whitney and paired *t*-test were used; significance was defined as a P value of less than .05. Statistical analysis was performed with Stata software (StataCorp LLC, TX).

Approval by the Institutional Ethics Committee was obtained.

RESULTS

A total of 36 patients were treated for acute blunt aortic trauma at our institution by endovascular repair; there were no open surgical procedures during this period. Mean age was 40.1 years (range 18 to 74), 31 (86.1%) were male. Trauma was caused by motor vehicle accident in 31 subjects (86.1%) and fall from height in 5 (13.9%). Mortality after treatment at 30 days was 2.7%. Two patients presented with nonisthmic distal descending thoracic aortic tears and one patient with a traumatic acute type B dissection; they were excluded from the study. CTA imaging was available for the remaining 33 patients (30 male) included in the study. Sixty-six individuals (60 male) were included in the control group.

In the trauma group 57.6% of the patients presented a bovine aortic arch; in the control group the prevalence was 34.8% ($P = 0.007$).

In the control group the mean and median distance between the common TBC-LCC trunk and the LSA were 12.4 mm (SD 5.9) and 13 mm (range 2−27 mm), respectively, for the bovine arch group and 7.8 mm (SD 6.1) and 5 mm (range 1−27 mm) between the LCC and LSA for the three-vessel arch anatomy group ($P < 0.005$). One patient with a nonbovine right aortic arch and a very unusual anatomy was excluded from this measurement. In the bovine arch group 60.9% of the subjects had a distance of 12 mm or greater compared with 22% in the three-vessel group ($P = 0.003$).

DISCUSSION

Aortic trauma after a high-energy accident is a lethal condition; most patients die before reaching a medical facility based on historical data generated

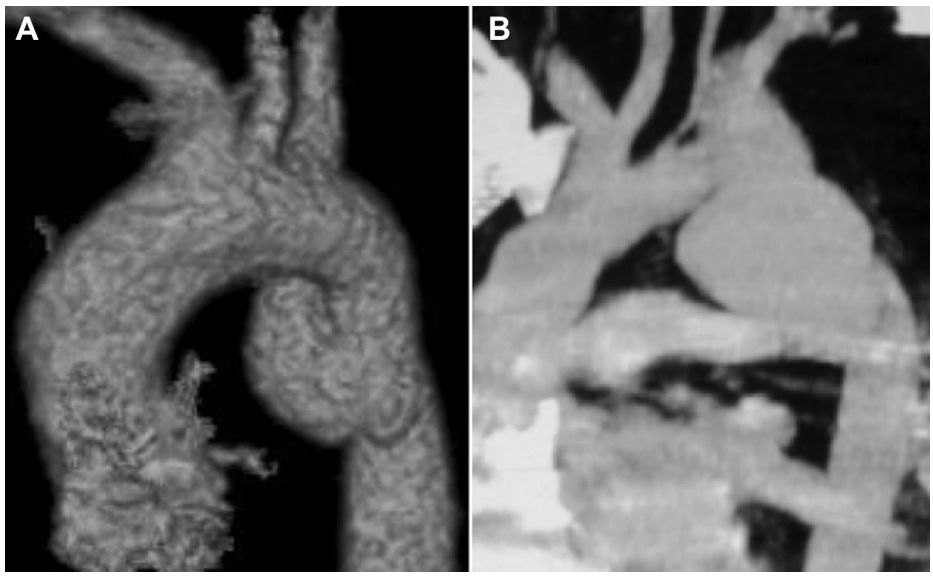

Fig. 1. CTA of blunt aortic trauma patients. **(A)** Three-vessel aortic arch, **(B)** Bovine arch, with a left common carotid originating from the brachiocephalic trunk.

60 years ago.[1] This has probably improved over time with faster victim rescue and transportation to dedicated trauma centers. Contemporary data still reports that 20–30% of the patients dying after high-energy blunt trauma present an aortic tear.[2,3]

An aortic bovine arch has been described in 13.6–14% of the European and USA population,[4,6] 14.6% in China,[7] 18.3% in Peru,[8] 11.4–17.2% in Colombia[9,10] and 34.5% in Argentina.[11] A higher incidence has been reported in South American (24.2%) and African (26.8%) populations compared to the United States and Europe in a metaanalysis that included worldwide literature,[4] but only two reports from South America were considered.[8,11] There are no prevalence reports from Chile. The 34.8% incidence we found in our sex-matched (91% male) control group is higher than described in other populations worldwide, but similar to the one described in Argentina, our neighbor country.[11]

A higher prevalence of bovine arch has been reported in patients with type B aortic dissection and aneurysmal disease;[6,12] type B dissection alone[13] has also been described as a possible predictor of increased long-term mortality in aortic dissection.[14] These findings have been challenged by other reports.[7] An increased shear stress on the inner curvature of the arch in patients with bovine arch has been described as a possible cause to explain these findings.[13]

A higher prevalence of a bovine aortic arch has also been described related to blunt trauma of the aortic arch branches.[15–18] This observation is based on a single-center experience[15]; they found that three of seven patients treated for blunt traumatic lesions of the BCT had a bovine arch. Later on, a few reports of single cases have driven to this conclusion. Since it is based on the prevalence found in very few patients that arrived alive to a hospital and were diagnosed and treated, there is an important bias: the prevalence in patients that expired before being diagnosed is unknown. Therefore concluding that a bovine arch is a risk factor facilitating rupture may be a mistake. We did find a higher incidence of bovine aortic arch configuration in patients treated for isthmic aortic blunt trauma.

We can reasonably assume that the prevalence of a bovine arch in subjects involved in an accident is equal to the general population of the same sex in that area. The fact that it is more prevalent in patients surviving long enough to be treated and up to 90% of the subjects with an unknown aortic arch anatomy never reach a hospital alive[1–3] has two possible explanations. It may be a condition that facilitates the aortic tear, as some concluded for the supraaortic trunks, or it ''protects'' the patient after it occurs preventing immediate exsanguinating hemorrhage and allowing treatment.

Anatomically, an obvious difference of the bovine and the more common three-vessel arch is the longer distance between the LSA and the common bovine trunk compared with the LSA to LCC artery distance, as we demonstrated in our control group. This segment of aorta has a different embryological origin than the rest of the arch. Even

though it is very hard to prove, it is possible that this longer segment of aorta provides also a larger area of elastic tissue to dissipate the deceleration energy of the trauma, probably causing a smaller tear and also providing a larger area of periadventitial and mediastinal connective tissue that can potentially contain the rupture, therefore preventing acute exsanguination.

Confirmation of this finding in a larger series and data on the incidence of bovine aortic arch comparing survivors and nonsurvivors of blunt aortic trauma cannot only increase the understanding of the mechanism of this lethal condition, but also provide information to improve safety measures in vehicle design.

LIMITATIONS AND CONCLUSIONS

Aortic blunt trauma patients are not common; only two cases per year have been treated at our institution during the 17-year period reviewed. In a recent review the average number of cases treated at institutions reporting results is only 25 patients.[19] The prevalence of bovine arch in subjects that do not survive the trauma and never reach a hospital has not been reported to the best of our knowledge and is a vital piece of information to allow firm conclusions.

Patients reaching out for treatment for isthmic aortic blunt trauma have a higher incidence of a bovine aortic arch and therefore a longer distance between the LSA and the next proximal great vessel. This finding and further research may provide a better understanding of the mechanism of this highly lethal injury, the conditions that facilitate survival and could eventually influence the design of safety measures.

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