

# Morphology of the Pattern of Branching of the Aortic Arch in Syrian Hamsters (*Mesocricetus Auratus*)

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## Research Article

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## Abstract

The branching patterns of the aortic arches of 28 adult male and female Syrian hamsters (SH) were thoroughly examined under a stereomicroscope for the first time by using latex injection and corrosion casting to determine their general arrangements and morphological variations as well as their differences and similarities to other rodents and rabbits. Three major arteries, namely, the brachiocephalic trunk (BC), left common carotid artery (CC) and left subclavian artery (SA), originating from the aortic arch (AR), were uniformly noted in SH. The BC was consistently divided into the right SA and the right CA. SA in SH normally releases the internal thoracic, deep cervical, dorsal scapular, vertebral, superficial cervical and supreme intercostal arteries. The costocervical trunk typically consisted of supreme intercostal and internal thoracic arteries and a common trunk for dorsal scapular and deep cervical arteries. To comprehend the comparative morphology of the pattern of branching of AR more completely, our results were compared with previous studies in rodents and rabbits. (1) The general morphology of the great arteries from AR in SH was similar to that in mole rats, rats, mice, porcupines, and gerbils but was essentially different from that in rabbits, guinea pigs, red squirrels, ground squirrels, pacas and chinchillas. (2) The typical pattern of the branching of the subclavian arteries in SH was similar to that in guinea pigs, rats, and rabbits but was different from that of the reported rodents regardless of the origins of the bronchoesophageal and internal thoracic arteries and the composition of the costocervical trunk.

## Introduction

Hamsters belong to the order Rodentia, suborder Myomorpha, and family Cricetidae. Approximately 90% of the hamsters used in research are of Syrian origin (Lossi et al. 2016). Syrian hamsters exhibit characteristics that make them desirable models for cardiovascular research (Suckow et al. 2012).

The aortic arch in domestic mammals gives rise to vessels that supply the head, forelimb and cranial region of the thorax as well as the thoracic region (Nickel et al. 1981). The branching pattern of the aortic arch has been described in various rodents, including rats (Green 1963; Hebel and Stromberg 1976; Popesko et al. 1992b), guinea pigs (Copper and Schiller 1975; Popesko et al. 1992a; Kabak and Haziroglu 2003), rabbits (Barone et al. 1980; Popesko et al. 1992a; Ozdemir et al. 2008; Martonos et al. 2018), gerbils (Oliveira et al. 2018), porcupines (Atalar et al. 2003), mole rats (Aydin et al. 2013), paca (Oliveira et al. 2001), red squirrels (Aydin 2011), ground squirrels (Aydin et al. 2011), spiny mice (Oto et al. 2010), and mice (Popesko et al. 1990b). No similar account in hamsters is available in the literature. The goals of this study were, therefore, (1) to clarify the general architecture and morphological variations of the aortic arch and its branches in Syrian hamsters and (2) to determine the morphological similarities and differences between the branching pattern of the aortic arch in Syrian hamsters and those of other rodents. Knowledge of the basic and comparative gross anatomical descriptions provided in the present study may provide an ideal animal model for human research in circulatory ailments and be of use for animal scientists and comparative morphologists.

## Materials And Methods

A total of 28 (15 males and 13 females) healthy adult Syrian hamsters weighing  $84.57 \pm 4.81$  g and body length  $137.35 \pm 4.67$  mm were purchased from the Razi Vaccine and Serum Research Institute and the Center of Comparative and Experimental Medicine, Shiraz University of Medical Sciences. Then, the animals were housed in an air-conditioned room and supplied with water and standard commercial chow ad libitum under conditions of a 12-hr light and dark cycle. All procedures were approved by the Local Ethical Committee for the use of animals in experiments (approval code: EE/99.3.02.15054/scu.ac.ir). The twenty-five Syrian hamsters (13 males and 12 females) were used for latex injection. The animal was placed in dorsal recumbency before administration of the anaesthesia. The animals were intraperitoneally anaesthetized with a combination of ketamine (Bremer Pharma GMBH, Germany), acepromazine (Alfasan, Netherlands), and xylazine (Alfasan, Netherlands) according to [https://www.mcgill.ca/research/files/research/112\\_hamster\\_anesthesia](https://www.mcgill.ca/research/files/research/112_hamster_anesthesia). Under anaesthesia, the thoracic cavity was opened and flipped over. Then, to prevent coagulation of the blood, heparin sodium (5000 IU/ml, Alborz Darou, Iran) was injected into the apex cordis. The animals were exsanguinated by cutting the caudal vena cava and the vessels were immediately perfused with sodium chloride (0.9%) via a cannula, which was inserted into the apex cordis to remove blood cloths during exsanguination; an average amount of 20 ml of sodium chloride solution for each specimen seemed adequate. Subsequently, red (Sahar colour, Tehran, Iran) coloured latex (1-Stop Solution, Kuala Lumpur, Malaysia) was hand injected into the apex cordis for about 5 second until the tips of the thoracic limbs were seen to be filled. Later, the apex was ligatured. The amount of latex used to obtain good visualization of the arteries of the aortic arch ranged from 1- 2 ml for each hamster. The injected specimens were fixed by immersion in 10% natural formalin solution which contained 4% formaldehyde. Three Syria hamsters (two males and one female) were examined by a corrosion cast technique. Vinyl resin (Rhodopas AX 90/10; Rhone-Poulenc; Courbevoie; France) in a 10% ketone solution was injected similar to the latex injection. The internal casts of the arterial branches of the aortic arch were obtained by macerating the specimens in 10% sodium hydroxide bath (Verli et al. 2007). All dissections were examined under a binocular stereomicroscope (Nikon, SMZ800, Japan). The dissection data were documented by digital images obtained with Samsung Mobil (South Korea, Galaxy J5, 2015). In the photographs, a part of a steel ruler was used as a scale bar and distance between the two lines was 1 mm. For the nomenclature of the aortic arch and its branches, Nomina Anatomica Veterinaria (2017) was applied.

## Results

The aortic arch was located at the level of the second intercostal space, and at this level, three great arterial branches, namely, the brachiocephalic trunk and the left common carotid and left subclavian arteries originating from the aortic arch, were uniformly noted on all 25 specimens (100.00%). The short brachiocephalic trunk was the first branch of the aortic arch, extended cranially and was divided into the right subclavian and right common carotid arteries at the level of the first intercostal space in 25 specimens (100.00%) (Fig. 1). Both the right and left subclavian arteries normally were given off within the thorax, supreme intercostal, and common trunk for the dorsal scapular and deep cervical arteries, as well as the internal thoracic, vertebral, and superficial cervical arteries.

The costocervical trunk was absent on 20/50 sides (40%), including 8/25 right sides (32%) and 13/25 left sides (52%) (Fig. 2). The costocervical trunk had two types on 30/50 sides (60%) as follows:

Type A: the costocervical trunk consisted of the supreme intercostal artery, a common trunk for the dorsal and deep cervical arteries on 16/50 sides (32%), including 8/25 right sides (32%) and 8/25 left sides (32%) (Fig. 3).

Type B: the costocervical trunk consisted of a common trunk for the supreme intercostal and internal thoracic arteries and a common trunk for the dorsal and deep cervical arteries on 34/50 sides (68%), including 21/25 right sides (84%) and 13/25 left sides (52%) (Fig. 4).

The supreme intercostal artery was the first branch arising from the dorsal surface of the subclavian artery. The supreme intercostal artery was usually given off of the first, second and third dorsal intercostal arteries. Shortly after its emergence from the subclavian artery, the supreme intercostal artery released a long first dorsal intercostal artery that coursed dorsally to reach the first intercostal space (Figs. 2, 3, 4).

The common trunk for the dorsal scapular and deep cervical arteries always originated from the subclavian arteries cranial to the origin of the costocervical trunk (when present) or from the supreme intercostal artery. The trunk passed dorsally and left the thoracic cavity from the first rib. The deep cervical artery was passed cranially to reach the muscles of the neck. The dorsal scapular artery was coursed caudally (Figs. 2, 3, 4).

The bronchoesophageal artery was a slender artery with extremely variable origins. The bronchoesophageal artery was coursed caudally and slightly ventrally over the aortic arch to reach the bronchus. The artery may arise from the supreme intercostal artery on 25/50 sides (50.00%), including 8/25 right sides (32%) and 17/25 sides (68%), or from the internal thoracic artery on 25/50 sides (50.00%), including 17/25 right sides (68%) and 8/25 left sides (32.00%) (Figs. 2, 3, 4).

The vertebral artery arises from the subclavian artery, cranial to the origin of a common trunk for the dorsal scapular and the deep cervical arteries. The vertebral artery began opposite the first intercostal space and passed dorsally and cranially to enter the transverse foramen of the sixth cervical vertebra (Figs. 2, 3, 4).

The superficial cervical artery was the last branch arising from the dorsal surface of the subclavian artery, cranial to the origin of the vertebral artery, at the level of the first intercostal space. Immediately, the ascending cervical artery was removed, which was the cervical continuation of the superficial cervical artery. The artery ascended cranially under the ventral cervical muscles. After that, the superficial cervical artery was on the left in the thoracic cavity until it passed dorsocranially between the neck and scapula (Figs. 2, 3, 4).

A relatively large internal thoracic artery originated separately from the ventral surface of the subclavian artery on the 18/50 sides (36%) and was positioned at the origin of the supreme intercostal artery or

costocervical trunk (when present) at the level of the first rib on the right side and at the level of the first intercostal space on the left side. The artery was then curved ventrally and caudally. The internal thoracic artery originated from a common trunk with the supreme intercostal artery from the subclavian artery on 32/50 sides (64%), including 10/25 right sides (40%) and 6/25 left sides (24%) (Figs. 2, 3, 4).

## Discussion

The aortic arch gives off two major arteries, the brachiocephalic trunk and the left subclavian artery in the chinchilla (Ozdemir et al. 2008; Martonos et al. 2018), guinea pig (Cooper and Schiller 1975; Popesko et al. 1992a; Kabak and Hazriroglu 2003), paca (Oliveira et al. 2001), red squirrel (Aydin 2011), ground squirrel (Aydin et al. 2011), and rabbit (Craigie 1969; Barone et al. 1973; Noden and De Lahunta 1985; Popesko et al. 1992a). However, the aortic arch in the Syrian hamster releases three major arteries, including the brachiocephalic trunk, left common carotid and left subclavian arteries, similar to those of rats (Green 1963; Hebel and Stromberg 1976; Popesko et al. 1992b; Constantinescu, 2018), mice (Cook 1965; Noden and De Lahunta 1985; Popesko et al. 1992b; Constantinescu 2018), porcupine (Atalar et al. 2003), mole rats (Aydin et al. 2013), gerbils (Oliveira et al. 2018), and spiny mice (Oto et al. 2010). Nevertheless, deviations from the typical pattern of great vessel branching can occur among members of the same species, especially in smaller domestic and laboratory animals (Noden and De Lahunta 1985).

### Brachiocephalic trunk

As in the rat (Green 1963; Hebel and Stromberg 1976; Popesko et al. 1992b; Constantinescu 2018), porcupine (Atalar et al. 2003), mouse (Cook 1965; Noden and De Lahunta 1985; Popesko et al. 1992b; Constantinescu 2018), spiny mouse (Oto et al. 2010) and gerbil (Oliveira et al. 2018), the brachiocephalic trunk in the Syrian hamster was given off the right common carotid and right subclavian arteries. However, the brachiocephalic trunk releases the left and right common carotid and right subclavian arteries in the chinchilla (Ozdemir et al. 2008; Martonos et al. 2018), guinea pig (Cooper and Schiller 1975; Kabak and Hazriroglu 2003), squirrel (Aydin et al. 2011), paca (Oliveira et al. 2001), red squirrel (Aydin 2011), ground squirrel (Aydin et al. 2011), and rabbit (Barone et al. 1973; Noden and De Lahunta 1985).

### Subclavian artery

The subclavian artery in rodents and rabbits is normally given off the internal thoracic and deep cervical, dorsal scapular, vertebral and supreme intercostal arteries. Two (in the mole rat; Aydin et al. 2013; in the guinea pig; Popesko et al. 1992a; Kabak and Hazriroglu 2003; rat: Hebel and Stromberg 1976; Popesko et al. 1990b), three (in the guinea pig: Cooper and Schiller 1975; in the rabbit: Barone et al. 1973), or four of these arteries (in the rabbit: Popesko et al. 1990a) may be fused into a common stem of origin, called the costocervical trunk. In the present study, three of these arteries formed the costocervical trunk. Moreover, the superficial cervical artery consistently originated from the subclavian artery at the thoracic inlet in the Syrian hamster, similar to that in all reported rodents and rabbits.

## **Costocervical trunk**

The presence of the costocervical trunk is also not mentioned or illustrated in the chinchilla (Ozamir et al. 2008; Martonos et al. 2018), rabbit (Angell-James 1974), red squirrel (Aydin 2011) and ground squirrel (Aydin et al. 2011). Branches of the costocervical trunk have also not been described in gerbils (Oliveira et al. 2018), mole rats (Aydin et al. 2013) or paca (Oliveira et al. 2001).

Similar to the guinea pig (Cooper and Schiller 1975; Popesko et al. 1992a; Kabak and Hazrioglu 2003), paca (Oliveira et al., 2001), gerbil (Oliveira et al. 2018), rat (Green 1963; Hebel and Stromberg 1976; Popesko et al. 1992b), rabbit (Barone et al. 1973; Popesko et al. 1992a), and porcupine (Atalar et al. 2003), the costocervical trunk emerged separately from the subclavian artery in the Syrian hamster. On the other hand, the right costocervical trunk may arise from a common trunk along with the vertebral artery in the porcupine (Atalar et al. 2003) or along with the deep cervical and internal thoracic arteries in the mole rat (Aydin et al. 2013) from the right subclavian artery. In addition, the left costocervical trunk together with the internal thoracic artery originates from a common trunk from the left subclavian artery in the mole rat (Aydin et al. 2013). Consequently, the costocervical trunk generally takes its origin as a separate trunk from the subclavian artery in rodents and rabbits except in the mole rat and porcupine.

The costocervical trunk generally represents a common trunk for the deep cervical and supreme intercostal arteries in the guinea pig (Kabak and Hazrioglu 2003) and rat (Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b), for the supreme intercostal, deep cervical, and descending (dorsal) scapular arteries in the guinea pig (Cooper and Schiller 1975) or for the supreme intercostal, deep cervical and descending (dorsal) scapular arteries in the rabbit (Barone et al. 1973; Popesko et al. 1992a). However, the trunk in the Syrian hamster usually consisted of the internal thoracic, supreme intercostal, deep cervical, and dorsal scapular arteries. Therefore, the composition of the trunk varies in rodents and rabbits.

## **Supreme intercostal artery**

As in guinea pigs (Popesko et al. 1992a; Kabak and Hazrioglu 2003), rats (Green, 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b), and rabbits (Barone et al. 1973; Popesko et al. 1992a), the supreme intercostal artery in the Syrian hamster generally originates from the costocervical trunk. However, the supreme intercostal artery directly emerges from the subclavian artery in chinchilla (Ozdemir et al. 2008; Martonos et al. 2018).

No information has been reported regarding the origin of the supreme intercostal artery in the porcupine (Atalar et al. 2003), gerbil (Oliveira et al. 2018), paca (Oliveira et al. 2001), and mouse (Popesko et al. 1992b; Constantinescu 2018).

## **Dorsal scapular artery (descending scapular artery)**

As in rabbits (Barone et al. 1973; Popesko et al. 1992a) and guinea pigs (Cooper and Schiller 1975), the dorsal scapular artery in the Syrian hamster always emerges from the costocervical trunk. In contrast, the

dorsal scapular artery originates directly from the subclavian artery in the red squirrel (Aydin 2011), ground squirrel (Aydin et al. 2011) and guinea pig (Kabak and Hazrioglu 2003) or forms the superficial cervical artery in chinchilla (Ozamir et al. 2008; Martonos et al. 2018).

On the other hand, the origin of the dorsal scapular artery was always a common trunk with the deep cervical artery in the Syrian hamster, whereas in the guinea pig, the left dorsal scapular artery may arise most frequently by a common trunk with the vertebral artery (Kabak and Hazrioglu 2003)

The exact origin of the dorsal scapular artery is not documented in rats (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b; Constantinescu 2018), mole rats (Aydin et al. 2013), gerbils (Oliveira et al. 2018), mice (Popesko et al. 1992b; Constantinescu 2018) or paca (Oliveira et al. 2001).

### **Vertebral artery**

There was only one vertebral artery on each half of the thoracic cavity in the Syrian hamster, similar to that in other rodents, including rats (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b), mice (Popesko et al. 1992b), porcupine (Atalar et al. 2003), chinchilla (Ozamir et al. 2008; Martonos et al. 2018), paca (Oliveira et al. 2001), mole rats (Aydin et al. 2013), red squirrels (Aydin 2011), ground squirrels (Aydin et al. 2011) and gerbils (Oliveira et al. 2018), as well as rabbits (Barone et al. 1973; Popesko et al. 1992a). On the other hand, the descriptions of the number of vertebral arteries in the guinea pig differ among authors. The vertebral artery was always double (*Cavia porcellus*: Popesko et al. 1992a; Shively and Stump 1974) or single (*Cavia coba*: Cooper and Schiller 1975) on each half of the body. In addition, the two right vertebral arteries were constantly present, but two left vertebral arteries were usually present in the guinea pig (*Cavia porcellus*: Kabak and Hazrioglu 2003).

As in the porcupine (Atalar et al. 2003), rat (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b; Constantinescu 2018), mouse (Popesko et al. 1992b; Constantinescu 2018), chinchilla (Ozamir et al. 2008; Martonos et al. 2018), guinea pig (Cooper and Schiller 1975; Popesko et al. 1992a; Kabak and Hazrioglu 2003), mole rat (Aydin et al. 2013), paca (Oliveira et al. 2001), red squirrel (Aydin 2011), ground squirrel (Aydin et al. 2011), and gerbil (Oliveira et al. 2018), as well as the rabbit (Barone et al. 1973; Popesko et al. 1992a), the vertebral artery in the Syrian hamster generally originated from the subclavian artery.

However, the right vertebral artery in porcupine (Atalar et al. 2003) and the right and left vertebral arteries in the guinea pig (Cooper and Schiller 1975) may arise from the costocervical trunk.

In the guinea pig, the first vertebral artery emerges directly from the subclavian artery, but the second vertebral artery may arise with the left dorsal scapular artery by a common trunk from the subclavian artery (Kabak and Hazrioglu 2003).

### **Deep cervical artery**

No information has been reported regarding the origin of the deep cervical artery in porcupine (Atalar et al. 2003), gerbil (Oliveira et al. 2018), paca (Oliveira et al. 2001), and mouse (Popesko et al. 1992b; Constantinescu 2018).

Similar to guinea pigs (Cooper and Schiller 1975; Popesko et al. 1992a; Kabak and Hazrioglu 2003), rats (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b), and rabbits (Barone et al. 1973; Popesko et al. 1992a), the deep cervical artery always originates from the costocervical trunk in the Syrian hamster. In contrast, the deep cervical artery may arise separately from the subclavian artery in the chinchilla (Ozdemir et al. 2008; Martonos et al. 2018), mole rat (Aydin et al. 2013), red squirrel (Aydin 2011), and ground squirrel (Aydin et al. 2011).

However, the right deep cervical artery emerged with the internal thoracic artery and costocervical trunk in the mole rat (Aydin et al. 2013). In addition, the deep cervical artery may arise from a common trunk from the subclavian artery in the red squirrel (Aydin 2011) and ground squirrel (Aydin et al. 2011). In contrast, the deep cervical artery in the Syrian hamster was removed from the dorsal scapular artery by a common trunk.

### **Superficial cervical artery**

The superficial cervical artery in the Syrian hamster originated separately from the subclavian artery, similar to that in the guinea pig (Popesko et al. 1990a; Kabak and Hazrioglu 2003) rabbit (Popesko et al. 1992a), rat (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b), paca (Oliveira et al. 2001), chinchilla (Ozdemir et al. 2008; Martonos et al. 2018), gerbil (Oliveira et al. 2018), red squirrel (Aydin 2011), mouse (Constantinescu 2018), and ground squirrel (Aydin et al. 2011).

However, the superficial cervical artery, together with the deep cervical and suprascapular arteries, emerge from a short common trunk from the subclavian artery in the red squirrel (Aydin 2011) and ground squirrel (Aydin et al. 2011). In addition, the right superficial cervical artery originates from the external thoracic artery by a common trunk from the right subclavian artery in the mole rat (Aydin et al. 2013).

In porcupine (Atalar et al. 2003), the exact origin of the superficial cervical artery is not documented. Consequently, the superficial cervical artery independently originates from the subclavian artery in rodents except in squirrels and mole rats.

### **Bronchoesophageal artery**

The exact origin of the bronchoesophageal artery is not documented in mole rats (Aydin et al. 2013), paca (Oliveira et al. 2001), red squirrels (Aydin 2011), ground squirrels (Aydin et al. 2011), gerbils (Oliveira et al. 2018), rabbits (Barone et al. 1973; Popesko et al. 1992a), porcupines (Atalar et al. 2003), rats (Green 1963; Walker and Homberger 1997; Popesko et al. 1992b), mice (Constantinescu 2018), or chinchillas (Ozamir et al. 2008; Martonos et al. 2018). However, the bronchoesophageal artery in the Syrian hamster was usually detached either from the supreme intercostal artery in 50% of cases or from the internal thoracic artery in 50% of cases. On the other hand, the bronchoesophageal artery in the

rat is detached from the internal thoracic artery (Hebel and Stromberg 1976) or from the thoracic aorta (Popesko et al. 1992b). The bronchoesophageal artery may also arise from the costocervical trunk (most frequently), right subclavian artery, or the internal thoracic artery in the guinea pig (Kabak and Hazrioglu 2003). Thus, the general origin of the bronchoesophageal artery exhibited significant differences between rodents and rabbits.

### **Internal thoracic artery**

The internal thoracic artery in the Syrian hamster usually originates from a common trunk with the supreme intercostal artery from the subclavian artery, similar to that reported in rabbits (Angell-James 1974), red squirrels (Aydin 2011), and ground squirrels (Aydin et al. 2011). However, the right internal thoracic artery together with the deep cervical artery and costocervical trunk may arise from a common trunk from the right subclavian artery, or the left internal thoracic artery originates from the costocervical trunk by a common trunk from the left subclavian artery in the mole rat (Aydin et al. 2013).

On the other hand, the internal thoracic artery arises independently from the subclavian artery in various rodents, including rats (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b; Constantinescu 2018), chinchillas (Martonos et al. 2018), guinea pigs (Cooper and Schiller 1975; Popesko et al. 1990a; Kabak and Hazrioglu 2003), paca (Oliveira et al. 2001), mice (Constantinescu 2018), gerbils (Oliveira et al. 2018), and rabbits (Barone et al. 1973; Popesko et al. 1990a).

### **External thoracic artery**

The external thoracic artery is released from the left and right subclavian arteries in mole rats (Aydin et al. 2013), but such an artery does not emerge from the subclavian artery in the Syrian hamster, similar to that of various rodents, including rats (Green 1963; Hebel and Stromberg 1976; Walker and Homberger 1997; Popesko et al. 1992b), mice (Popesko et al. 1992b), porcupine (Atalar et al. 2003), chinchilla (Ozamir et al. 2008; Martonos et al. 2018), paca (Oliveira et al. 2001), mole rats (Aydin et al. 2013), red squirrels (Aydin 2011), ground squirrels (Aydin et al. 2011) and gerbils (Oliveira et al. 2018), as well as rabbits (Barone et al. 1973; Popesko et al. 1992a).

### **The order of branches arising from the subclavian artery**

The order in which the artery arose from the subclavian artery showed several variations in the Syrian hamster, other rodents and rabbit.

The first branch arising from the dorsal surface of the subclavian artery exhibited variations in rodents and rabbits. The first branch was the costocervical trunk in the mole rat (Aydin et al. 2013), guinea pig (Cooper and Schiller 1975; Kabak and Hazrioglu 2003), rabbit (Popesko et al. 1992a), rat (Green 1963; Hebel and Stromberg 1976; Popesko et al. 1992b), mouse (Constantinescu, 2018) or vertebral artery in the rabbit (Barone et al. 1973; Angell-James 1974), paca (Oliveira et al. 2001), gerbil (Oliveira et al. 2018), porcupine (Atalar et al. 2003), mouse (Popesko et al. 1992b) and ground squirrel (Aydin et al. 2011) or the

supreme intercostal artery in the chinchilla (Ozamir et al. 2008; Martonos et al. 2018), mouse (Popesko et al. 2011). In this study, the coscervical trunk was the first branch arising from the subclavian artery.

The superficial cervical artery in the Syrian hamster was the last branch, usually arising from the dorsal surface of the subclavian artery, similar to that seen in all reported rodents and rabbits.

## Conclusions

The following conclusions were reached: (1) Intraspecific variations were noted in the presence and composition of the costocervical trunk, the origin of the bronchoesophageal artery, and the formation of a common trunk by the internal thoracic artery and supreme intercostal between the right and left subclavian arteries in the Syrian hamster. (2) The origins of the bronchoesophageal and internal thoracic arteries and the composition of the costocervical trunk in the Syrian hamster were different from those of the previously reported rodents and rabbits. (3) The origin of the deep cervical and supreme intercostal arteries in the Syrian hamster was very similar to that in the guinea pig, rat, and rabbit but was different from that of the reported rodents. (4) The origin of the vertebral artery was extremely consistent among rodents and rabbits except in the porcupine. (6) The origin of the dorsal scapular artery in the Syrian hamster was similar to that in the guinea pig and rabbit but was different from that of the reported rodents. (7) The origin of the superficial cervical artery in the Syrian hamster was similar to that in the guinea pig, rat, rabbit, chinchilla, and gerbil but was different from that in the reported rodents. (8) The typical pattern of branching of the subclavian arteries in the Syrian hamster was similar to that in the guinea pig, rat, and rabbit but was different from that of the reported rodents regardless of the origin of the bronchoesophageal and internal thoracic arteries as well as the composition of the costocervical trunk.

## Declarations

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### Conflicts of interest

The authors declare no conflicts of interest.

### Author Contributions

Conceptualization, data curation, formal analysis, investigation, methodology, resources, Supervision, validation, visualization, and writing - review & editing was performed by **Jamal Nourinezhad**. Review & editing was performed by Reza Ranjbar. Formal analysis, investigation, validation, and visualization were performed by Vahid Rostamizadeh, Marzieh Norouzi Tabrizinejad, and Abdulaziz Hallak. Methodology, resources, validation, and writing - review & editing was performed by Maciej Janeczek. All authors approved the final manuscript.

## Data Availability

*The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.*

## Ethics approval

All procedures were approved by the Local Ethical Committee for the use of animals in experiments (approval code: EE/99.3.02.15054/scu.ac.ir).

## Consent to participate

Not applicable.

## Consent to publish

Not applicable.

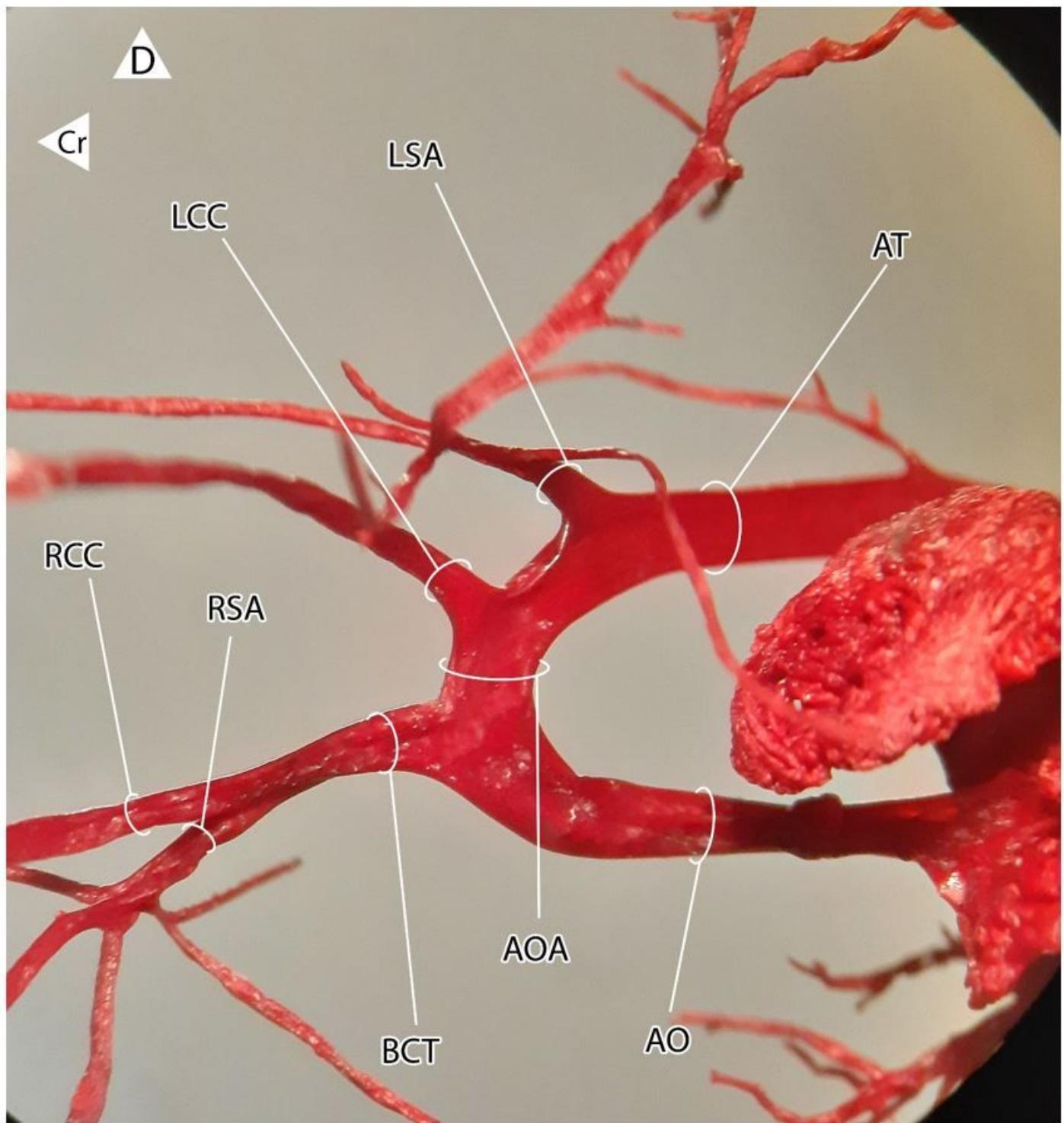
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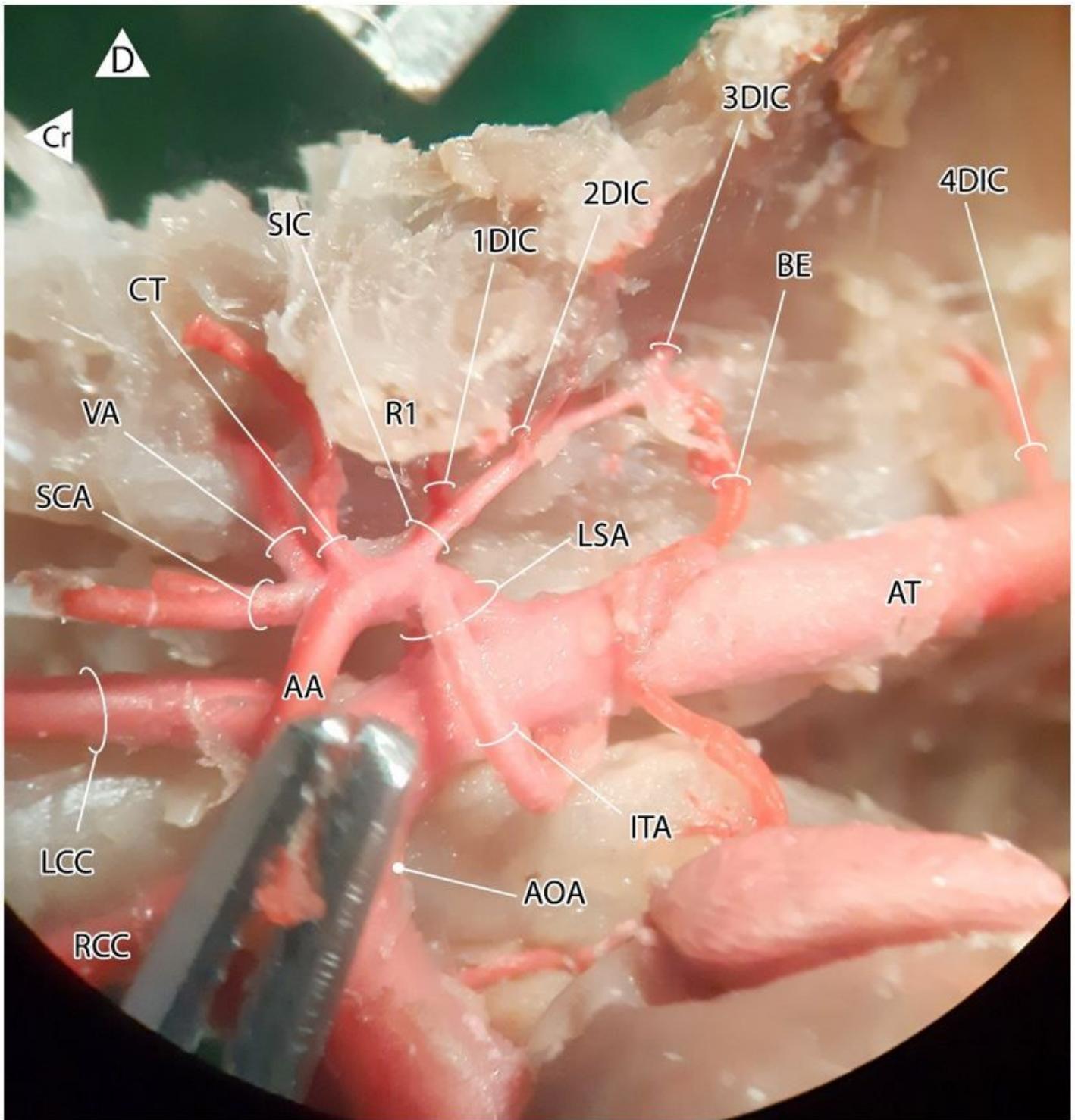
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## Figures



**Figure 1**

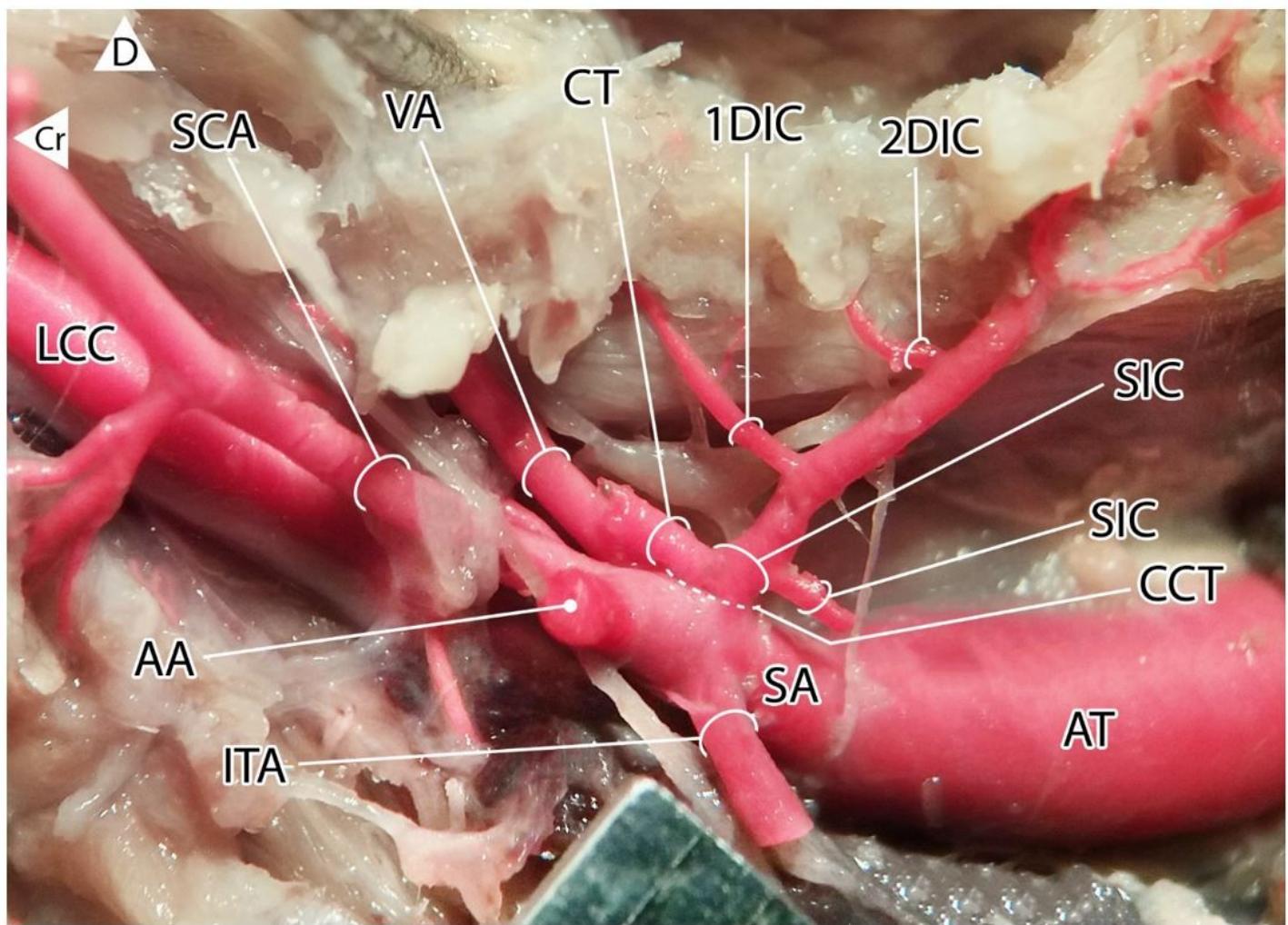
Corrosion cast of the major arteries of the aortic arch in the Syrian hamster. Lateral view of the left side.  
AO: Ascending aorta, AOA: Aortic arch, AT: Aortic thoracic, BCT: Brachiocephalic trunk, CR: Cranial, D: Dorsal, LCC: Left common carotid artery, LSA: Left subclavian artery, RCC: Right common carotid artery, RSA: Right subclavian artery.



**Figure 2**

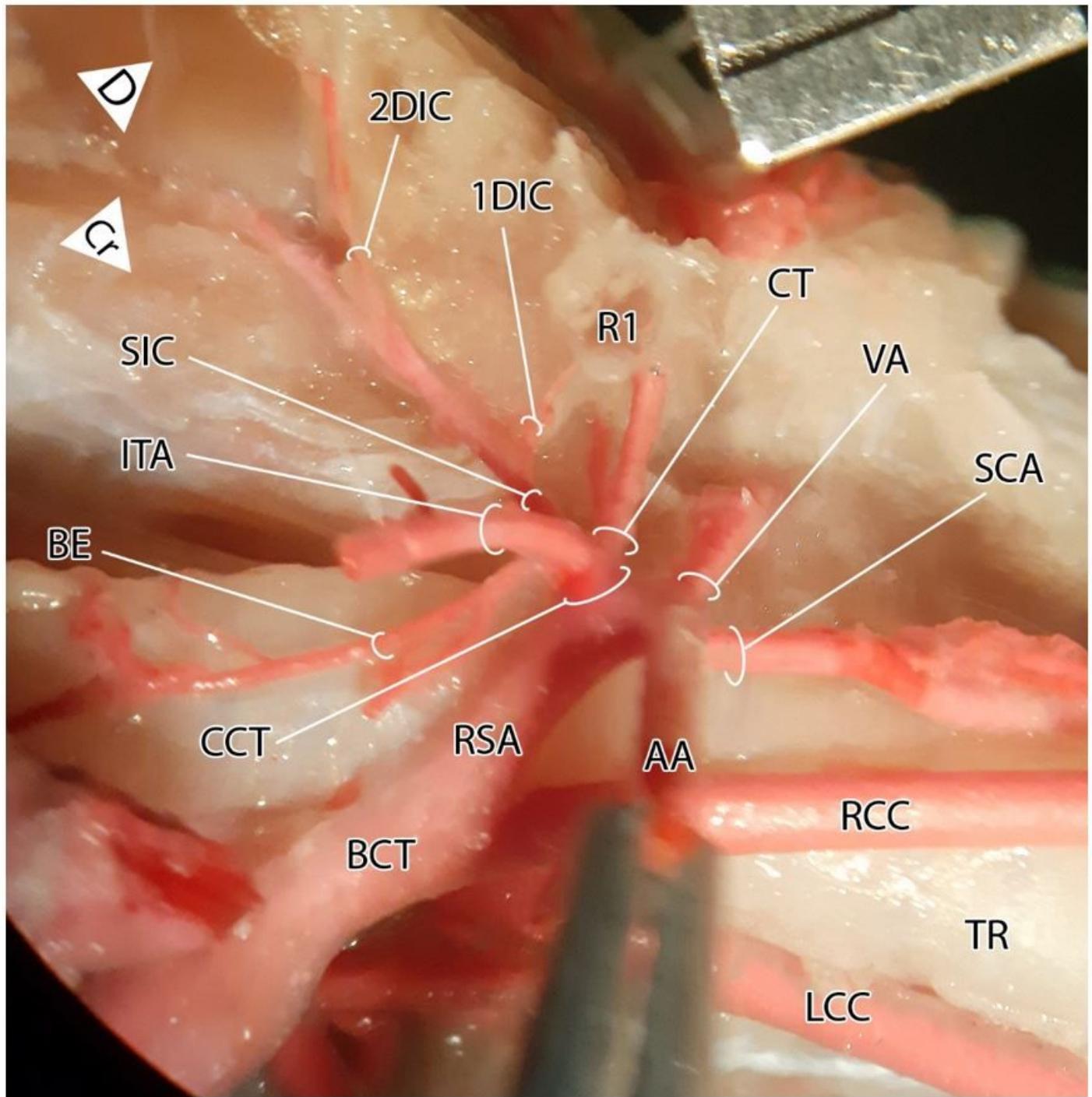
Red latex injection of the branching of the aortic arch in the Syrian hamster. Lateroventral view of the left side. The costocervical trunk is absent. The bronchoesophageal artery (BE) arises from the supreme intercostal artery. AA: Axillary artery, AOA: Aortic arch, AT: Aortic thoracic, BE: Bronchoesophageal artery, CR: Cranial, D: Dorsal, CT: Common trunk for the deep cervical and dorsal scapular arteries, ITA: Internal thoracic artery, LCC: Left common carotid artery, RCC: Right common carotid artery, R1: First rib, SA:

Subclavian artery, SCA: Superficial cervical artery, SIC: Supreme intercostal artery, VA: Vertebral artery, 1–4DIC: First to fourth dorsal intercostal arteries.



**Figure 3**

Red latex injection of the branching of the aortic arch in the Syrian hamster. Lateral view of the left side. The costocervical trunk (CCT) consists of the supreme intercostal and a common trunk for the deep and dorsal scapular arteries. The bronchoesophageal artery (BE) originates from the supreme intercostal artery. AA: Axillary artery, AT: Aortic thoracic, BE: Bronchoesophageal artery, CR: Cranial, D: Dorsal, CT: Common trunk for the deep cervical and dorsal scapular arteries, ITA: Internal thoracic artery, LCC: Left common carotid artery, SA: Subclavian artery, SCA: Superficial cervical artery, SIC: Supreme intercostal artery, VA: Vertebral artery, 1–2DIC: First to second dorsal intercostal arteries.



**Figure 4**

Red latex injection of the branching of the aortic arch in the Syrian hamster. Lateral view of the right side. The costocervical trunk (CCT) consists of the internal thoracic, supreme infrastatic, and a common trunk. The bronchoesophageal artery (BE) arises from the internal thoracic artery. AA: Axillary artery, AOA: Aortic arch, AT: Aortic thoracic, BE: Bronchoesophageal artery, CR: Cranial, D: Dorsal, CT: Common trunk for the deep cervical and dorsal scapular arteries, ITA: Internal thoracic artery, LCC: Left common carotid artery,

RCC: Right common carotid artery, RSA: Right subclavian artery, R1: First rib, SCA: Superficial cervical artery, SIC: Supreme intercostal artery, VA: Vertebral artery, 1–2DIC: First to third dorsal intercostal arteries.