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Circulatory system

Comprehensive review of the superficial veins of the forearm from a historical, anatomical and clinical point of view

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Abstract

The superficial veins of the forearm are prone to possess different patterns of anastomosis. This is highly significant, as venipunctures in the upper limb are among the most performed procedures in the world and they often rely on the veins of the cubital fossa. In addition, the relationship of these veins to the cutaneous nerves are also prone to vary and are often uncertain. These veins are also manipulated in the creation of arteriovenous fistula for dialisis, which remains as the best choice of treatment for renal failure patients. Such fistulas are often performed on the wrist or the cubital fossa, with the cephalic vein or basilic vein. It is known that anatomical variations of the vessels and nerves on the cubital fossa may induce the professionals to error, and one of the most common complications of venipuncture are accidental nerve puncture, which can lead to paresthesia and pain. We aim to perform a comprehensive review of the venous arrangements of the cubital fossa and their clinical aspects, as well as of venipuncture from a historical perspective and of the complications of venipuncture and arteriovenous fistula from an anatomical point of view, with the purpose of compiling available data and help healthcare professionals to reduce puncture errors or arteriovenous fistula complications and improve patient care.

Keywords

Cubital fossa, venipuncture, history, anatomical variations, superficial veins.

Introduction

The superficial veins of the forearm are often used for venipuncture and subsequent drug infusions. Furthermore, they are also manipulated during the creation of arteriovenous fistulas in hemodialysis patients (Lee et al., 2015,Reyes II, 2016,Yammine, Erić, 2016).

These veins may acquire different anatomical arrangements and anastomosis, especially in the antecubital region. Furthermore, their relations with cutaneous nerves may also vary (Mikuni et al., 2013,Pires et al., 2018,Yamada et al., 2008,Yammine, Erić, 2016).

Despite being one of the most common and often performed procedures, venipunctures are invasive and often painful, thus requiring knowledge regarding the

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morphological and functional aspects of the venous vessels as well as their anatomical relationships (Fukuroku et al., 2016,Mikuni et al., 2013,Moore et al., 2014,Tsukuda et al., 2016).

In addition, the rates of venipuncture failure are often attributed to difficulty in assessing the veins of the forearm, and the quality of the venous access is directly related to the quality of the performed procedure (Ialongo, Bernardini, 2016,Lewis et al., 2013). Lack of knowledge may lead to repetitive attempts in cases where the veins are not prominent enough, which can lead to complications such as hemorrhage and phlebitis (Fukuroku et al., 2016,Kim et al., 2017)

In the field of arteriovenous fistulas, knowledge of the venous arrangements of the cubital fossa may imply better outcomes and lower complications rates of the procedure (Jindal et al., 2006,Quencer, Arici, 2015,Reyes II, 2016).

The review presented herein aims at recollecting historical, anatomical and clinical data regarding these superficial vessels with the purpose to improve knowledge in this area and help clinicians to make successful venipuncture procedures.

Review

History of the circulatory system and venipuncture

The study of the circulatory system began with Hippocrates and Galen, in ancient Greece. However, their dissections were performed in animals such as monkeys, pigs and dogs, and as a result their anatomical description lacked precision and was incorrect in several aspects (Goss, 1961,Persaud et al., 2014).

Despite their inaccurate descriptions, the superficial veins of the forearm were already being used centuries ago (especially the median antecubital vein) to draw blood by means of bloodletting and phlebotomy. These procedures were often used as a treatment for several conditions, e. g. seizures and fever (Greenstone, 2010,Parapia, 2008).

The median antecubital vein was often the site for bloodletting due to its relation with the bicipital aponeurosis: it prevented the physician to accidentally cut the brachial artery (Testut, Latarjet, 1958). Due to this property, some authors referred to the bicipital aponeurosis as the "fascia of the grace of God" (Burdan et al., 2016,Lacombe, 1988,Moore et al., 2014).

In the XVII century, anatomists such as Sylvius and Vesalius revolutionized the anatomical world with their descriptions based on human dissections (King, 1970,Persaud et al., 2014).

Intravenous therapies were not studied until the XIV century, although the focus was placed in blood transfusion therapy. The first documented use of blood transfusion was in Rome (1492). The Pope Innocent VIII was in a coma and his physician thought that blood transfusion would cure him, thus, he obtained blood from three healthy young men and started the therapy. Not long after, the three men and the Pope died (Rivera et al., 2005).

After this tragic event, intravenous infusions weren't the focus of research until Williiam Harvey's description of the circulatory system in his book *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus*". Harvey described not only the systemic and pulmonary circulation, but the venous valves as well. Thus, he enhanced knowledge regarding the cardiovascular system (Mandarim-de-Lacerda, 1990,Payne et al., 1998).

During this period, there was a tragic yet important event involving a servant, which was unjustly accused of infanticide (her baby was stillborn) and sentenced to death by hanging. With the purpose of speeding her death, she asked her friends to beating her up whilst hanging. Her cadaver was obtained by the anatomy laboratory of the Oxford University, but she was still alive, albeit with a faint pulse and weak breathing. This event severely impacted the students and teachers on the scene and inspired Christopher Wren and Richard Lower to develop instruments for intravenous infusions and make research on this procedure (Felts, 2000,Hughes, 1982,Rivera et al., 2005).

Concomitantly, there were several attempts to inject opium into the veins of dogs, although they yielded poor results due to the lack of specialized instruments and lack of knowledge regarding blood coagulation (Felts, 2000,Rivera et al., 2005)

The first real form of intravenous therapy was during the cholera outbreak in Europe (1831), due to poor sanitary conditions. Cholera is known to be a disease that causes symptoms such as diarrhea and vomit, thus, there is the need to maintain the hydric balance. William Brooke O'Shaughnessy deduced this hypothesis in 1832 and together with Thomas Latta – his student – they successfully injected (continuously) a saline solution in the basilic vein of a cholera patient, whom survived the disease (Jackson, 2003,Peterfreund, Philip, 2013,Rivera et al., 2005).

With the creation of the hollow needle in 1845 by Rynd (he wanted to intravenously administrate morphine to treat trigeminal neuralgia), with the advent of the hypodermic needle created by Charles Pravaz in 1853 and with the fabrication of the glass syringe devised by Georg Luer in 1869, intravenous therapies began to evolve and became more common among healthcare professionals (Duque, Chagas, 2009,Rivera et al., 2005)

Nowadays, venipuncture and intravenous infusion are among the most performed procedures in the world. It is important to notice that the evolution of venipuncture was paced together with more complex understanding of the morphology and physiology of the venous system, the creation of newer devices properly created for specific types of treatment and infusion demand/flow as well as newer mechanisms to provide and improve the quality and safety of this procedure (Lewis et al., 2013,Strauss et al., 2008,Zarychanski et al., 2009)

Anatomy of the superficial veins of the forearm

The superficial veins are situated between the two layers of the superficial fascia and are accompanied by cutaneous nerves and superficial lymphatic vessels. They usually possess valves and communicate with the deep venous system by the perforating veins (valveless vessels) (Gardner et al., 1978,Goss, 1977,Latarjet, Liard, 1993,Moore et al., 2014,Testut, Jacob, 1952,Testut, Latarjet, 1958).

Three great veins can be observed on the forearm: the basilic vein (BV), which arises from the medial side; the cephalic vein (CV), which arises from the lateral side; and the median antebrachial vein, which arises between these two vessels. The CV and the BV are product of the dorsal venous network of the hand, while the median antebrachial vein is originated by the small veins from the palmar surface of the hand (Goss, 1977,Testut, Jacob, 1952,Testut, Latarjet, 1958).

As they reach the antecubital fossa, these veins acquire different forms of anastomosis (Pires et al., 2018,Yammine, Erić, 2016). The description here is a review of what is described in anatomical textbooks, while their arrangements and variations are addressed further in the text.

Classically, several authors describe and depict an arrangement in which the median antebrachial vein joins the median cubital vein – a vessel that rises from the CV and flows into the BV – or in the absence of the median cubital vein, the median antebrachial vein bifurcates and originates the median basilic vein and the median cephalic vein, joining the BV and the CV respectively. The latter arrangement is known as the "Classic M" or Y-shaped (Goss, 1977,Testut, Jacob, 1952,Testut, Latarjet, 1958).

It is important to remind that the median basilic vein and the median cephalic vein were removed from the "Terminologia Anatomica" (Del Sol et al., 2007), however these names are still used in research articles (Corzo Gómez et al., 2010,Del Sol et al., 2007,Yammine, Erić, 2016) and new anatomical textbooks (Moore et al., 2014) as they are fundamental to understand the venous patterns.

There is mention in the literature regarding the accessory cephalic vein as well. This vessel originates from a smaller plexus on the dorsal aspect of the forearm, the medial end of the dorsal venous network and joins the CV. Furthermore, it can also originate from a more distal portion of the CV. (Goss, 1977,Testut, Jacob, 1952,Testut, Latarjet, 1958).

According to Gardner et al. [20]), the superficial veins of the forearm are the main channels for the venous return. This is accordance with Testut, Latarjet [62](1958), as the authors explain that these veins are remnants of the upper limb bud development and that during ontogenesis the deep veins ran towards them.

In addition, the superficial veins of the forearm are larger than the deep ones and are subjected to the actions of the muscles in the arm and forearm (Testut, Latarjet, 1958).

The cubital fossa and the venous arrangements of the superficial veins

The cubital (or antecubital) fossa is a triangular space with its apex pointed distally to the limb. Its lateral and inferior boundary is the brachioradial muscle, while the pronator teres muscle binds the cubital fossa medially and inferiorly. The base of the "triangle" is done by an imaginary horizontal line between both epicondyles of the humerus. Its floor is formed by the brachial and the supinator muscles, while its roof is composed by the superficial fascia, subcutaneous tissue and the skin (Ellis, 2010,Pires et al., 2018,Testut, Jacob, 1952).

The deep content of the cubital fossa includes the distal biceps tendon, the brachial artery, the median and the radial nerves, while the superficial content includes the CV, BV, median cubital vein and the lateral and medial cutaneous nerves of the forearm. These structures are separated by the bicipital aponeurosis (Ellis, 2010,Moore et al., 2014,Testut, Jacob, 1952). As previously stated, these elements - specially the venous ones - are prone to vary in this region. Furthermore, their anatomical relationships with other structures are subject to variation (Corzo Gómez et al., 2010,Del Sol et al., 2012,Pires et al., 2018,Yamada et al., 2008,Yammine, Erić, 2016).

First, we will describe the several patterns reported in the literature and briefly comment anatomical variations of other elements present in the cubital fossa.

The venous arrangement of the cubital fossa has been studied by several authors, and some have shown regional, side and gender differences among their populations (AlBustami et al., 2014,Berry, Newton, 1908,Charles, 1932,Corzo Gómez et al., 2010,Del Sol et al., 2007,Del Sol et al., 2012,Doyle, 1968,Hamzah et al., 2014,Okamoto, 1922,Ukoha et al., 2013,Yamada et al., 2008,Yammine, Erić, 2016). However, their comparison is difficult due to differences in methodology and numerous distinct classifications of venous anastomoses (Pires et al., 2018).

For instance, the "Type 1" (Figure 1) according to Yammine, Erić [68](2016) is the classic venous arrangement shaped like the letter M or Y. This type was the second commonest, according to their paper.

This pattern was described as type A (Ukoha et al., 2013,Wasfi et al., 1986), 2 (AlBustami et al., 2014), 3 (Charles, 1932,Hamzah et al., 2014), 3-B (Halim, Abdi, 1974), 5 (Corzo Gómez et al., 2010), and some authors classified it as type 1 (Lee et al., 2015,Singh et al., 1982,Yamada et al., 2008). When these studies are further analyzed, it can be seen that some authors only describe the M pattern when the accessory cephalic vein is present (Del Sol et al., 2007), which characterizes the seventh type according to the classification proposed by Yammine, Erić [68](2016).

There is also confusion among anatomical textbooks. As previously observed, in Gray's Anatomy textbook the author assumes that the M type is the same as the Y

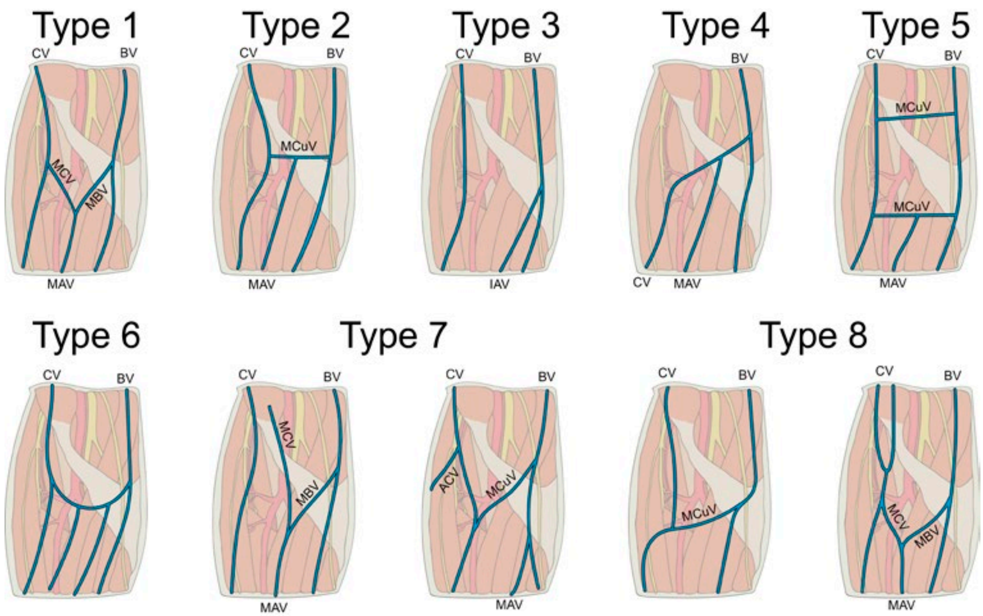

Figure 1. The venous patterns of the cubital fossa. CV = cephalic vein; BV = basilic vein; MAV = median antebrachial vein; MCuV = median antecubital vein; MBV = median basilic vein; MCV = median cephalic vein; ACV = accessory cephalic vein.

type, due to the disposition of the median antebrachial vein (Goss, 1977), despite that Sobotta's anatomical atlas refers to the Y shaped type as the one in which the CV joins the BV and there is only a rudimentary vein running towards the arm in the place of the CV (Jasiński, Poradnik, 2003,Sobotta, 2013).

Furthermore, Gardner et al. (1978) illustrate a pattern in which the accessory cephalic vein replaces the CV on the arm, although no such pattern has been described in the literature and it is not mentioned in the textual part of that book. There was only description of a similar pattern in a paper by Halim, Abdi [25](1974) in which, instead of the accessory cephalic vein, a deep vein from the cubital fossa replaced the CV in the arm, however no other paper describes this situations.

In order to avoid confusion, we propose that future works adopts the classification by Yammine, Erić [68](2016) as it is the most complete and versatile. The types are resumed in Table 1 and are depicted in Figure 1.

Type 2 was the most prevalent (44%-60%), followed by type 1 (20%-25%), type 7 (roughly 13%), type 3 (4%-11%), type 8 (roughly 8%), type 6 (approximately 4.5%), type 4 (3%-4%), and type 5 (approximately 2.4%) (Yammine, Erić, 2016).

The CV is not prone to vary in the arm and axilla, although it can be absent or rudimentary and sometimes it can completely join the external jugular vein or communicate with it (Araujo et al., 2017,Bergman et al., 1988,Loukas et al., 2008). A rudimentary state, but not absence of the BV in the arm has been described (Tubbs et al., 2016).

Variations of the brachial artery in the cubital fossa include its early division into radial and ulnar artery (Testut, Jacob, 1952,Testut, Latarjet, 1958). Its high division can produce the variations known as the superficial ulnar artery or the superficial radial artery (although this variant is rarer). These arteries are located on the superficial fascia, together with the superficial veins and the cutaneous nerves (Gruber, 1867,Narayanan, Murugan, 2017,Testut, Jacob, 1952,Testut, Latarjet, 1958,Tubbs et al., 2016). The bicipital aponeurosis (*lacertus fibrosus*) may be absent (Tubbs et al., 2016).

The cutaneous nerves in the cubital fossa also present different dispositions in respect to the superficial veins (Mikuni et al., 2013,Yamada et al., 2008). The lateral cutaneous nerve of the forearm is a branch of the musculocutaneous nerve, while the medial cutaneous nerve of the forearm comes directly from the medial cord of the brachial plexus (Goss, 1977,Latarjet, Liard, 1993,Testut, Latarjet, 1958). These nerves are often situated above the superficial veins and are more frequently present on the medial side of the cubital fossa (Mikuni et al., 2013,Yamada et al., 2008).

In the next section we will describe how all of these variations affect the procedures performed in the cubital fossa.

Clinical significance

The superficial veins of the forearm are commonly used in the clinical practice for venipuncture and arteriovenous fistulas for hemodialysis patients, as they are easy to reach and drain a significant portion of the upper limb blood (Elamurugan, Hemachandar, 2017,Gardner et al., 1978,Kumar et al., 2007,Lewis et al., 2013,Reyes II, 2016,Testut, Latarjet, 1958).

Superficial venous access is extremely relevant for daily clinical practice, as it can be used for numerous purposes, such as drug infusion, contrast injection to perform several exams, and collection of blood samples (Ialongo, Bernardini, 2016,Lewis et al., 2013).

Complications of venipuncture can involve the aforementioned anatomical variations. Cutaneous nerve injury and accidental arterial cannulation have been reported due to the spatial disposition of the cutaneous nerves and the variant known as superficial ulnar artery, respectively (Ramos, 2014,Shivappagoudar, George, 2013).

We remind that iatrogenic drug infusion in arterial vessels may produce an extremely painful sensation which can develop to ulceration. This condition is known as *embolia cutis medicamentosa* or Nicolau syndrome (Chagas et al., 2016,Duque, Chagas, 2009). Accidental arterial puncture may also produce aneurysms or pseudoaneurysms (Leite et al., 2017).

The accidental puncture of cutaneous nerves can produce acute sharp pain (electrical-type pain) and paresthesia on the territory of the afflicted nerve. This can happen either during the moment of the puncture or several hours later. These symptoms often disappear on their own, although several patients have to seek medical help to relieve the symptoms (Kim et al., 2017,Ramos, 2014,Tsukuda et al., 2016). It is stated that most of these injuries involve the lateral cutaneous nerve of the forearm (Ialongo, Bernardini, 2016).

In addition, venipuncture possesses high failure rates (up to 30%), and often requires multiple attempts. Factors such as lack of skill, difficulty in assessing and observing the superficial veins or the age of the patients often compromise the success of this procedure. Repetitive attempts can often lead to high extravasation rate, hematoma, hemorrhage and phlebitis (Fukuroku et al., 2016,Ialongo, Bernardini, 2016,Kim et al., 2017).

Anatomical studies observed that the most dangerous region is near the medial margin of the antecubital fossa, due to the presence of more sensorial branches, and the safer zone would be the radial part of the antecubital fossa (Mikuni et al., 2013,Yamada et al., 2008). According to anatomical textbooks the most used vein for venipuncture is the median cubital vein, as it is large and more prominent (Gardner et al., 1978,Moore et al., 2014). The radial portion of the median cubital vein is the safest region to perform venipuncture (Yammine, Erić, 2016).

With the purpose of reducing iatrogenic errors during venipuncture, several institutions have adopted the new vein visualization display system, which works through near-infrared light and accurately displays the superficial venous network. Thus, it can be used as a guide during venipuncture procedures (Fukuroku et al., 2016,Lee et al., 2015).

Variations of the CV can interfere with peripheral insertion of a central catheter, in which the CV is punctured near the cubital fossa and a catheter is placed near the right atrium. As such, knowledge of its absence, rudimentary state and anastomoses become highly significant (Araujo et al., 2017,Chopra et al., 2014). Furthermore, the absence of the CV associated with venous compression on the medial end of the forearm or axilla can lead to cyanosis and swelling of the limb (Imanishi et al., 1998).

Arteriovenous fistula is the most frequently performed procedure for dialysis. It is recommended nearly in all cases due to lower rates of failure, infection, steal syndrome and thrombosis, as well as higher lifespan in comparison to other treatments (Quencer, Arici, 2015).

The preferred sites for AVF creation are the wrist (radial artery and CV) and elbow (brachial artery and CV), although the BV can be used as well. The use of lower limb veins is not recommended. Despite that, each patient possess unique characteristics, thus, eligible sites for AVF creation are often individualized (Jindal et al., 2006,Kumar et al., 2007). The median antebrachial vein or the median basilic vein can be used in cases in which the CV was rudimentary or had a small caliber (Elamurugan, Hemachandar, 2017).

Evaluation of the caliber, length and possible obstruction sites of the vein and artery is necessary. Complications such as aneurysm formation, thrombosis and steal syndrome are highly dependent on the quality of the used vessels (Jindal et al., 2006).

Moreover, the superficial veins of the upper limb can be sites of aneurysms (Faraj et al., 2007,Katsoulis et al., 2003,Yaylak et al., 2007) and superficial vein thrombosis (Cosmi, 2015), which further makes the study of these vessels relevant.

Conflicts of interest

The authors have no conflict of interest to declare.

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