Short History of Vascular Injections, with Special Reference to the Heart Vessels

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Abstract

Vascular injections of colored mixtures were probably not performed before the seventeenth century. They are intended to allow a more detailed description of arteries, veins and lymph vessels, but also to produce specimens to be exhibited in anatomical and natural sciences museums, usually after corrosion. This paper gives a summary of the development of vascular injection procedures and mixtures in the seventeenth and eighteenth centuries, with special reference to the injection of the heart vessels (coronary arteries, venae cordis minimae, and lymphatics).

Introduction

The knowledge of the course and ramifications of blood vessels was based for a long time on the dissection of non injected vascular systems. Only large vessels could therefore be described, for the small branches were usually cut off during the dissection. Galen recommended introducing a wooden probe into the vessels during the dissection, so that the knife could not damage their walls. This procedure was still in use in the seventeenth century. Covert Bidloo (1649-1713), among others, depicted wooden probes in the heart cavities on a plate of his famous 1685 treatise (figure 1). The problems with these probes were two in number. First, they could not be introduced into very small vessels. Second they were not flexible and therefore compromised the course and relationships of the vascular system. That is why it became necessary to develop vascular injection procedures on the one hand, and to find color injections mixtures on the other hand (table 1). In addition to the scientific aspect of these procedures (detailed anatomical description of the vascular system), vascular injections were also intended to produce long lasting specimens for anatomical and natural sciences museums which drew crowds in the eighteenth century.

Figure 1. Plate 9 of Bidloo's treatise, engraved by Gerard de Lairesse (1685). Wooden probes are introduced into the heart cavities to show their communications with the large vessels.

The development of vascular injection procedures

Vascular injections may have been performed by anatomists as far back as in the Middle Ages. Alessandra Gigliani, who assisted the famous Bolognese anatomist Mondino dei Luzzi (ca. 1275-1326) in his lectures, is sometimes regarded as the first one to have been successful in «injecting blood vessels with various colored substances» (Martin, 1934). However, no information could be found concerning the nature of these substances and the injection procedure. Moreover, this hypothesis has been rejected by most of historians of anatomy, who question Gigliani's biographical data (Wolf-Heidegger and Cetto, 1967; Olry, 1997).

Leonardo da Vinci (1452-1519) is known to have performed wax injections into the brain ventricles, and «injec-

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tions of a solidifying liquid into the body» (Cazort et al., 1996). We could therefore infer that he probably also used vascular injections to study the course of blood vessels and the morphology of the heart cavities although there is no definitive proof that he used vascular injection (O'Malley and Saunders, 1952; Huard, 1968; Kurz, 1992).

Though Andre Vesale (1514-1564) described in his 1543 treatise a U-shaped tube (siphon) to perform injections, it seems that he never used it for the injection of blood vessels (Kurz, 1992). Moreover, this instrument appears neither on the plate depicting the dissection and preparation instruments in the 1543 edition, nor on the frontispiece of the fifth 1604 edition. A detailed description of this «Sipho anatomicus» was made about two centuries later (1746) by the German anatomist Georg August Langguth (1711-1782) (figure 2).

In the mid-seventeenth century, the surgeon Wilhelm Fabricius von Hilden (1560-1634) used an injection apparatus composed of a cannula linked to a dried bladder. A funnel and two faucets allowed the filling of the bladder and prevented the back flow of the injected mixture from the vessels to the cannula (figure 3). Subsequently, many famous anatomists tried to improve on this kind of injection apparatus: Regnier De Graaf (1668), Francis Glisson (1677), Richard Lower (1708), Stephen Hales (1733-1734), Alexander Monro (1733), Johann Nathanael Lieberkuhn (1789) (figure 4), Ludwig Teichmann (1879), and Gustav Schmiedel (1930), among others.

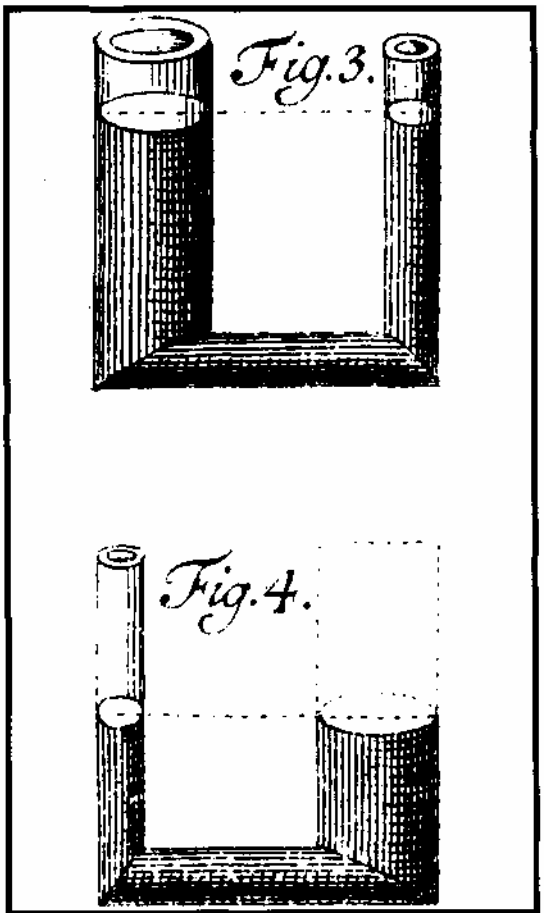

Figure 2. The «sipho anatomicus» by G. A. Langguth (1746).

The development of vascular injection substances

Many experiments were performed using various vascular injection mixtures in order to enhance the results (table 1). As far back as in 1522, Giacomo Berengario da Carpi (ca. 1460-1530) performed vascular injections with warm water, using a syringe. Thirty years later, Bartolomeo Eustachi (1520-1574) used the same procedure on renal arteries, and could observe the filling of the bladder.

However, the best vascular injection procedure results

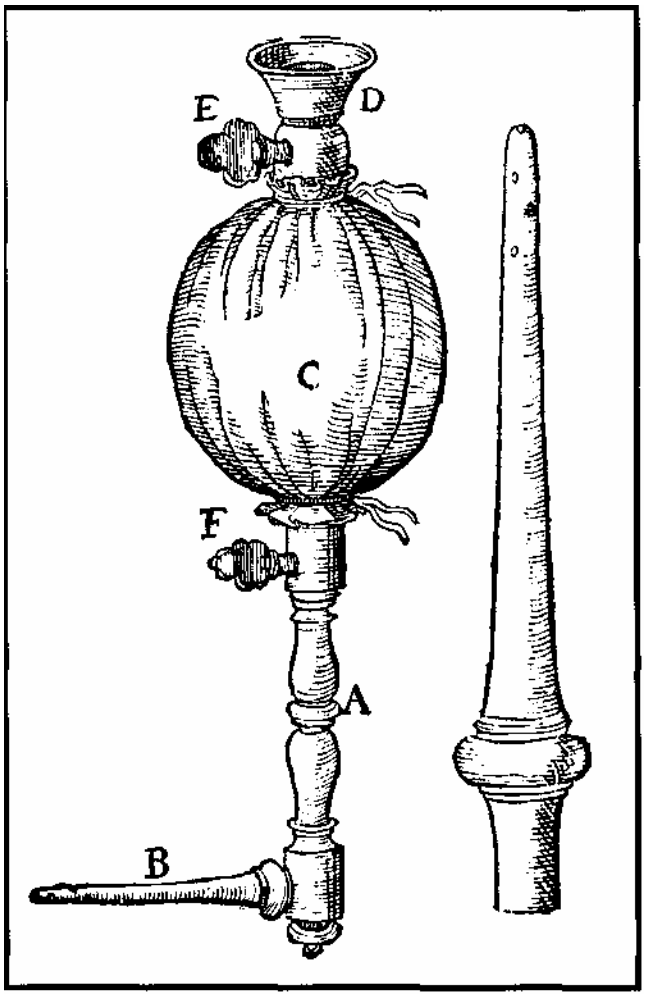

Figure 3. The injection apparatus described by W. F. von Hilden (1646). A and B: tube linked to a cannula. C: dried bladder. D: funnel. E and F: faucets.

were obtained by the Dutch anatomists Jan Swammerdam (1637-1680) and Frederik Ruysch (1638-1731). In 1672, Jan Swammerdam injected melted wax into the vessels of the uterus using a copper syringe (Fort, 1902). The specimens were so attractive that Frederik Ruysch decided to improve on the method. In the early eighteenth century, he was aknowledged as the «apostle of the injection technique* (Hagelin, 1989), and his striking specimens drew crowds in anatomical museums. Fontenelle said that «in a way, Ruysch's mummies prolong life, whereas Egyptian mummies only prolong death» (cited by Fort, 1902). The vascular injections of the specimens were so successful that Ruysch wanted to keep the composition of his injection mixture secret. He only called it «Materia ceracea». However, its composition was published twelve years after his death. It was composed of tallow, white wax, cinnabar, and «sometimes other substances, depending on the seasons* (Kurz, 1992).

In the late seventeenth century, Homberg injected blood vessels with a mixture of lead, tin and bismuth (1699); unfortunately, the results were disappointing. Finally, gelatin was used for the first time in vascular injection by Ronhaut, the surgeon to the King of Sardinia (1718).

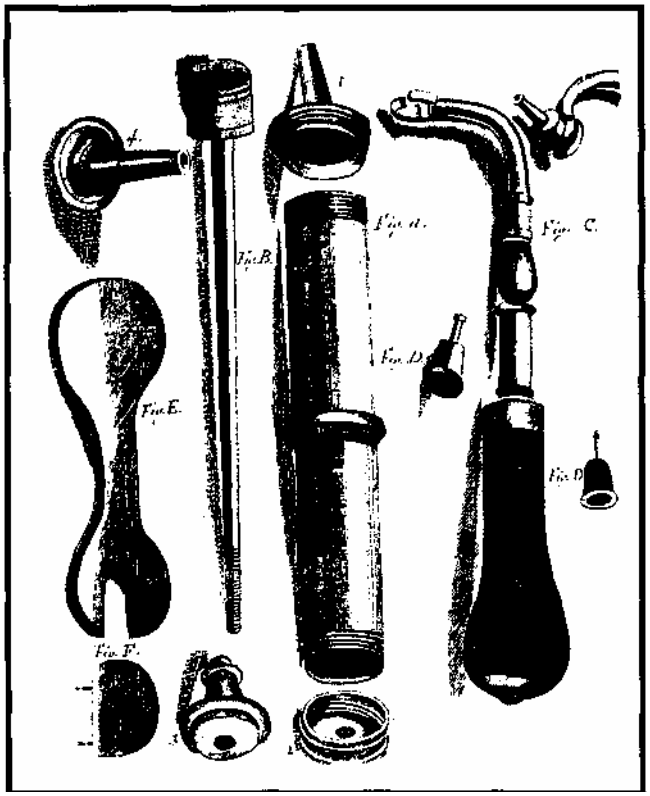

Figure 4. Syringes for vascular injections after J. N. Lieberkuhn (1789).

Heart vessels injections

A wonderfull specimen of injected coronary arteries was depicted in Frederik Ruysch's Opera omnia (1726) (figure 5). This specimen shows the ascending aorta, the right coronary artery and some of its ventricular branches, and the left coronary artery with its division into anterior interventricular and circumflex arteries. Numerous atrial rami are to be seen, arising from both coronary arteries. A large left conus artery is depicted, leaving the anterior interventricular artery near its start, and anastomosing on the conus with that of the right coronary artery.

The discovery of the opening of the venae cordis minimae into all cardiac cavities, is commonly attributed to the German anatomist Adam Christian Thebesius (1708). However, the existence of these minimal veins (Aho, 1950), which are more difficult to demonstrate than larger cardiac vessels, was first reported by Raymond Vieussens in a letter addressed to M. Boudin in 1706. Raphael Bienvenu Sabatier gives a detailed account of Vieussens' procedure in a memoir of 1792. For this experiment, Vieussens used two human hearts. He tied both venae cavae, the pulmonary trunk and the aorta. Then, he injected slowly a saffron tinting into the left coronary artery, and could observe that both atrial and ventricular left cavities became full of yellowish liquid. Moreover, the right cavities remained uncolored. Thebesius only confirmed the existence of these veins in his Latin dissertation (1708), by injecting water and colored wax into the cardiac veins.

Though Olof Rudbeck (1630-1702) discovered the subpericardial lymph vessels as far back as 1653, the systematization of the lymphatics of the heart was not understood before the second half of the nineteenth century (for the history of injection procedures of lymphatics in general, see Olry and Motomiya, 1997). The subendocardial lymph network was discovered by Eberth and Belajeff (1866), the epicardial ventricular lymph network by Sappey (1874), and the epicardial atrial lymph network by Rainer (1907) and Mouchet (1909).

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Table 1. Some landmarks in the history of vascular injection.

Author	Date	Substance	Equipment
A. Gigliani (?)	Early XlVth century	Various colored substance	7
L. da Vinci (?)	1504-1507	Wax	7
G. B. da Carpi	1522	Warm water	Syringe
A. Vesale	1543	7	Siphon
W. F. von Hilden	1615	7	Cannula linked to a bladder
J. Swammerdam	1672	Melted wax	Copper syringe
G. Homberg	1699	Lead, tin, bismuth	Pneumatic apparatus
R. Vieussens	1706	Saffron tinting	?
A. C. Thebesius	1708	Water, colored wax	?
F. Ruysch	1726	"Materia ceracea"	7
Ronhaut	1718	Gelatin	?
G . A. Langguth	1746	7	Sipho anatomicus

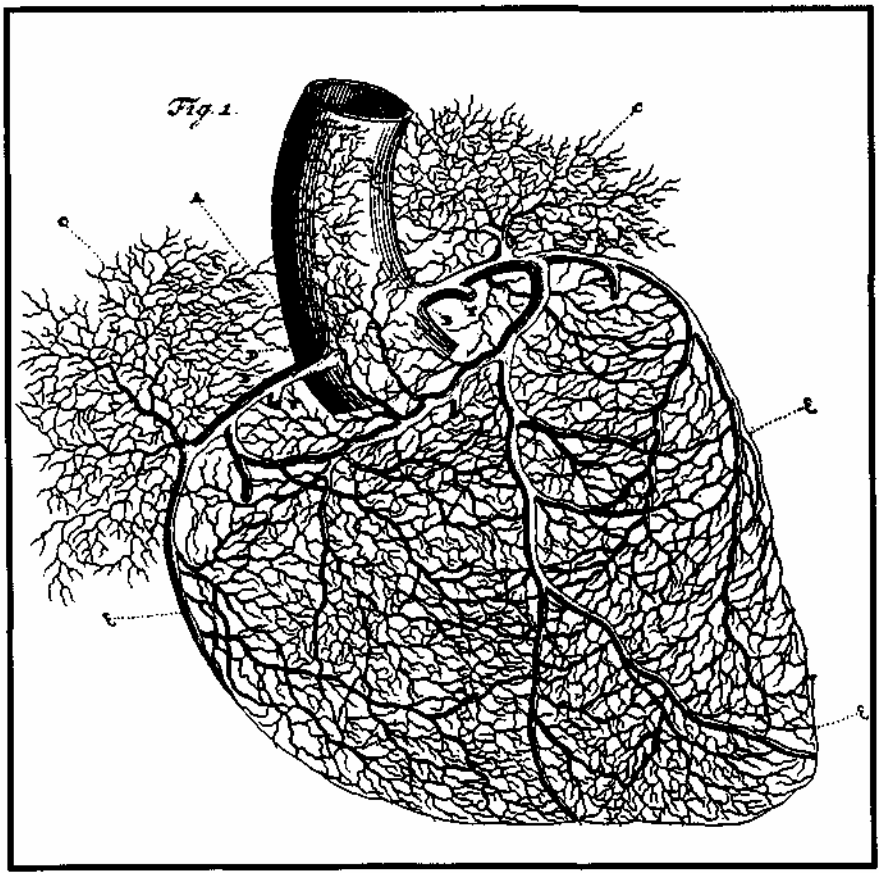

Figure 5. Vascular injected specimen of the heart by F. Ruysch (1726).

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Peripheral vascular disease (PVD) is a slow and progressive circulation disorder caused by narrowing, blockage or spasms in a blood vessel.Â PVD may affect any blood vessel outside of the heart including the arteries, veins, or lymphatic vessels. Organs supplied by these vessels, such as the brain, and legs, may not get enough blood flow for proper function. However, the legs and feet are most commonly affected. Peripheral vascular disease is also called peripheral arterial disease. What causes peripheral vascular disease?Â History of heart disease. Male gender. Postmenopausal women. Family history of high cholesterol, high blood pressure, or peripheral vascular disease. Risk factors that may be changed or treated include: Coronary artery disease. Vascular resistance occurs where the vessels away from the heart oppose the flow of blood. Resistance is an accumulation of three different factors: blood viscosity, blood vessel length, and vessel radius.[8]. Blood viscosity is the thickness of the blood and its resistance to flow as a result of the different components of the blood.Â Damage, due to trauma or spontaneously, may lead to hemorrhage due to mechanical damage to the vessel endothelium. In contrast, occlusion of the blood vessel by atherosclerotic plaque, by an embolised blood clot or a foreign body leads to downstream ischemia (insufficient blood supply) and possibly necrosis. Vessel occlusion tends to be a positive feedback system; an occluded vessel creates eddies in the normally laminar flow or plug flow blood currents. Heart disease today is considered the top preventable disease in the United States. However, heart disease has been described and studied by people across the world since the times of ancient Egypt. Read on to learn more about the history of heart disease and what the future might hold for those with heart disease.Â A look back at the history of heart disease may surprise you. Even Egyptian pharaohs had atherosclerosis. At the 2009 American Heart Association meeting in Florida, researchers presented study results showing that Egyptian mummies, some 3,500 years old, had evidence of cardiovascular disease â€” specifically atherosclerosis (which narrows the arteries) in different arteries of the body.