World J Surg
DOI 10.1007/s00268-016-3481-6

SURGICAL HISTORY

Andreas Vesalius' 500th Anniversary: First Description of the Mammary Suspensory Ligaments

Romy J. Brinkman[1] · **J. Joris Hage**[1]

Abstract Sir Astley Paston Cooper has, to date, been acknowledged to be the first to describe the suspensory ligaments of the breast, or Cooper's ligaments, in 1840. We found these ligaments to be recorded in the first edition of *'De Humani Corporis Fabrica Libri Septem'* by Andreas Vesalius, published in 1543. To commemorate Vesalius' 500th birthday, we quote and discuss this earlier record. Vesalius' record of the nature and function of the *fleshy membrane* between mammary gland and pectoral muscle, the *hard fat* intervening the mammary glands, and the *fibers running from the fleshy membrane to the skin* are a clear representation of posterior layer of the superficial fascial system, the fibro-adipose stroma surrounding and linking the mammary glandular elements, and the suspensory ligaments as we know them. Vesalius recorded the anatomy and function of the latter structures nearly 300 years before Sir Astley Paston Cooper did.

Introduction

The shape of the female breast is the result of many factors including muscular and skeletal thoracic contour, total mammary volume, fat content, glandular content, its connective tissue complement, and the quality of the overlying skin. In the inactive mammary gland, connective tissue is abundant and glandular elements are minimal. These glandular elements consist of lobules of potential secretory tubules that are surrounded by a loose, fine-fibered, vascular connective tissue with numerous fibroblasts, the intralobular connective tissue [1, 2]. Between the lobules are masses of dense collagenous fibers, the interlobular connective tissue, in which varying amounts of adipose tissue are present [2–4]. During pregnancy and lactation, the loose intralobular connective tissue enables the continued expansion of the glandular tubules and alveoli. The dense interlobular connective tissue then appears as septa between the expanded lobules of glandular tissue. This fibroglandular parenchyma of the breast is caught between the anterior, or superficial layer and posterior, deep layer of the superficial fascial system (SFS) that exists in the subcutis throughout the body and is referred to as 'Scarpa's fascia' in the abdominal wall [5]. The dense interlobular connective tissue posteriorly connects with this deep layer that is intimately associated with the pectoralis major muscle fascia, and anteriorly with the superficial layer and the dermis [6]. This way, these so-called suspensory ligaments of the breasts provide structural support for the breast [2].

To date, Sir Astley Paston Cooper (1768–1841) has been acknowledged as having been the first to record these ligaments and their function, in his book *On the anatomy of the breast* published in 1840 [4, 6–8]. Such acknowledgment denies the earlier record by Andreas Vesalius (1515–1564), the founder of modern anatomy, in his *De Humani Corporis Fabrica Libri Septem* (*De Fabrica*) that

✉ J. Joris Hage
j.hage@nki.nl

[1] Department of Plastic and Reconstructive Surgery, Netherlands Cancer Institute-Antoni van Leeuwenhoek Hospital, Plesmanlaan 161, NL-1066, CX, Amsterdam, The Netherlands

Published online: 04 March 2016

was published in 1543 [9]. To commemorate Vesalius' 500th birthday, we present and discuss his recordings of these ligaments and other observations on the mammary parenchyma and compare them with those of Cooper.

Methodology

The text of Vesalius' Book V—The organs of nutrition and generation of *De Fabrica* was searched for references to the mammary parenchyma and the mammary suspensory ligaments and their function. For this inventory, we used the digital copy of the first print of *De Fabrica* (1543) [9] and its English translation provided by Richardson and Carman [10].

Results

In the passage 'Substance' of chapter XVIII on 'The breasts' in Book V of *De Fabrica* on the organs of nutrition and generation, Vesalius recorded that '*the substance of which* [the breasts] *are composed is glandulous; it contains a great deal of fat and is interwoven with veins and just a few arteries and nerves'* (quote on p. 202) [10]. On the '*form and pattern*' of the mammary gland, Vesalius noted that '*there is a single large gland shaped like a breast at the centre of the nipple, beside which lie in a circle a large number of others, all small and resembling almonds with their husks removed; they are joined and linked to each other by hard fat with the intervention of veins and fibers running from the fleshy membrane to the skin*' (quote on p. 203) [10].

Thus, Vesalius already recognized that the glandular elements consist of lobules and that adipose tissue is present between these lobules (Fig. 1). He furthermore recognized the specific fibro-adipose character of this tissue as *hard fat with the intervention of .[..]. fibers*. That Vesalius understood these *fibers* to run from the deep layer of the SFS to the skin, becomes clear from a following sentence in which he recorded that '*the whole substance of the breasts is in fact contained like fat between the skin and the membrane described by us as fleshy, and the breasts are linked to the muscles that lie upon the ribs by exactly the*

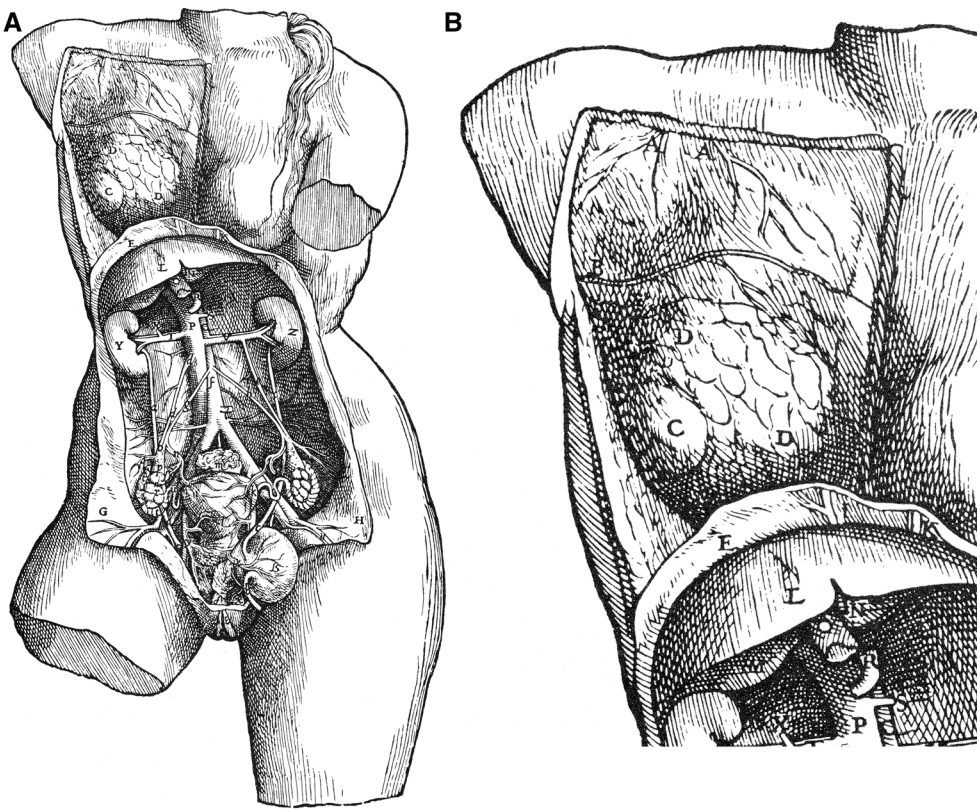

Fig. 1 **a** Tabula XXV of Book V of Vesalius' *De Humani Corporis Fabrica Libri Septem* on the organs of nutrition and generation showing how *'we have removed the skin from the right breast of the present figure so as to show as far as possible the nature of the breasts'* (quote on p. 40) [10]. **b** Detail of Tabula XXV showing *'C: principal body of the breast'* and *'DD: glandules and fat covering the glandulous body marked C'* (quote on p. 40) [10]. (Illustration taken from [15]. This historical work is no longer copyright protected)

same connection as the fleshy membrane is linked to the underlying muscles over the rest of the body.' (quote on p. 202) [10]. In Book II of *De Fabrica* on the ligaments and muscles, Vesalius defined the *fleshy membrane (membrana carnosa)* as *'the membrane lying under the skin of the whole body. It is attached here and there by fibers to the muscles that lie under it, but is more strongly attached to the skin'* (quote on p. 143) [11]. In previous work, we explained that Vesalius' fleshy membrane is the equivalent of the stratum membranosum of the SFS as we currently know it [12]. Obviously, Vesalius failed to note that the SFS in the breast bifurcates in a superficial layer and deep layer. He only recognized its deep layer overlying the pectoralis muscle fascia. By his recording that the intervening fibers in the hard fat between the glandular lobules run from the fleshy membrane to the skin, Vesalius indicated the mammary suspensory ligaments *avant la lettre*.

Vesalius furthermore observed that '*However much flaccid breasts may on occasion droop down, the fleshy membrane does not part company with the muscles, but the glands and the fat, being no longer constricted, become flaccid and draw apart from the fleshy membrane'* and that breasts in '*women who are lactating and in the last months of pregnancy.[..]. do not preserve the same tone and the hard fat no longer holds* [the breasts] *up, they gradually become flaccid and droop'* (quote on p. 203) [10]. In other words, Vesalius held not the SFS (*fleshy membrane)*, but the flaccidity of fibro-adipose stroma and suspensory ligaments responsible for ptosis of the breasts. This way, he acknowledged the significance of the suspensory ligaments as a structure of support, shape, and firmness of the breast.

Discussion

To date, Cooper's *On the anatomy of the breast* published in 1840 [8], and his *The anatomy and diseases of the breast* published in 1845 [13] have been considered the first detailed, recorded analysis of breast anatomy [4, 6, 7]. Cooper's primary interest was breast anatomy as it related to physiology, as he stated '*it is necessary that the breast employed for the purpose should be that of a woman who has been for some time suckling*' (quote on p. 6, respectively p. 19) [8, 13]. Consequently, his interest in mammary fat was incidental and focussed mostly on its importance for the volume of the breast [7]. Still, his understanding of the relationship of this fat to the fibroglandular parenchyma is clear from his remark that '*in a large and fat person the breast is far removed from skin, and from the pectoralis major muscle, by the immense quantity of adipose matter placed before and behind the gland, and in the intervening structures'* in the section of his text on 'The fat and cellular tissue' (quote on p. 71, respectively p. 58; emphasis added by Nickell and Skelton) [7, 8, 13].

Unlike Vesalius, Cooper recognized both the superficial, and deep layer of the SFS. He described how the *'fascia mammae..[..].. divided into two layers; the superficial, and the deeper layer of the breast, between which the gland of the breast is included. If I begin to trace this fascia from the sternum, I find both layers adhering to the ligamentous substance which covers that bone. From thence they proceed towards the breast, when one layer separates from the other, to include the breast between them'* (quote on p. 48, respectively p. 45) [8, 13].

His description of the suspensory ligaments, however, differed from that of Vesalius and from current definitions (Fig. 2). Rather than running from the SFS deep layer to the SFS superficial layer and dermis through the entire thickness of the fibroglandular parenchyma, Cooper restricted the extension of the suspensory ligaments to the anterior part of this parenchyma only: '*The anterior or superficial layer passes upon the anterior or cutaneous surface of the breast: here it forms a fibrous covering, but not a true capsule, spread upon the surface of the gland, and passing between the gland and the skin; but it also enters the interior of the secretory structure. Here it sends out two sets of processes of a fibrous nature from its two surfaces. Anteriorly, large, strong, and numerous fibrous or fascial processes, to the posterior surface of the skin which covers the breast, and to the substance of which it is received, and with which it is incorporated. It is by these processes that the breast is suspended in its situation, and I shall therefore call them the ligament suspensoria. By these processes, the breast is slung upon the forepart of the*

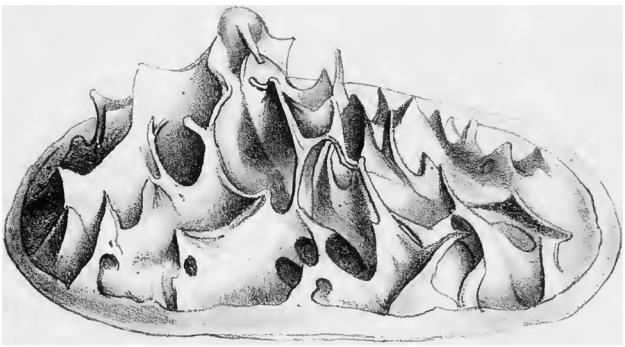

Fig. 2 Plate IV—Ligamenta Suspensoria and Sections of Cooper's *The anatomy and diseases of the breast* showing *'A preparation made to show the ligamenta suspensoria supporting the folds of the breast to the inner side of the skin. The nipple is seen in the centre, a portion of skin in the circumference, and the folds of the breast are sustained by the ligamenta suspensoria, which are continued to the skin; but their connexion with it is here cut off. Thus the surface of the breast is greatly increased, while its diameter remains the same'* (plate and quote between p. 130 and p. 131) [13]. (Illustration taken from [8]. This historical work is no longer copyright protected)

chest, for they form a moveable but very firm connexion with the skin, so that the breast has sufficient motion to elude violence; yet by this fibrous tissue it is, excepting under age, lactation, or relaxation, prevented from much change of place. The ends of these ligaments are spread out and incorporated with the posterior surface of the skin, and give it its whiteness and firmness. When raised and dried, the preparations of these ligamentous processes form a curious, irregular surface of folds, between the skin and the mammary gland. They are seen in a section of the breast, spread out and lost upon the inner surface of the skin and their anterior extremities. When the breast is placed in its natural position, the posterior extremities of the ligament suspensoria are spread over the forepart of the gland, support numerous folds of the glandular structure, penetrate the substance of the organ, and every where connect the portions of the glands to each other' (quote on pp 49–50, respectively pp 45–46) [8, 13].

When describing the posterior or deep layer of the SFS, Cooper did not refer to the suspensory ligaments: '*Whilst the anterior or superficial layer of fascia is thus spread over the anterior surface of the breast, the posterior or deeper seated layer, when it has reached the margin of the gland, passes behind it, and sends forth two layers of fibers. The anterior of these fibers pass on the back of the gland, sending processes of fascia into the organ to unite its parts, and other fibers which pass from one ridge of the gland to the other posteriorly, giving it a smoother surface than that of the anterior part of the breast, as it is not folded in the same manner. The other fibers of this deeper seated fascia pass backwards, and are united to the aponeurosis of the pectoralis major*' (quote on p. 50–51, respectively p. 46) [8, 13]. He even stressed that '*thus, then, the breast is supported by the two portions of the fascia; the superficial layer connecting it to the skin anteriorly, and forming the ligament suspensoria, and the posterior layer of fascia joining it to the pectoral muscle, by its aponeurosis; and between these two processes it swings, and yields to pressure and to violence'* (quote on p. 51, respectively p. 46) [8, 13].

Obviously, Cooper felt that the suspensory ligaments and overlying skin together acted as an "natural brassiere." In his view, the fibroglandular parenchyma is locked to, and suspended by, the overlying skin by way of the ligaments that cover and enter this parenchyma anteriorly. Vesalius description of the *'fibers running from the fleshy membrane to the skin*' (quote on p. 203) [10] corresponds better to the current understanding of the suspensory ligaments running through the entire thickness of the parenchyma from the SFS deep layer that is intimately associated with the pectoralis major muscle fascia, to the SFS superficial layer and the dermis [6]. That the anatomist Vesalius, unlike the surgeon Cooper, failed to note the surgically detectable anterior layer of the SFS may be explained by it being seldom identified in the cadaver [14].

Still, like Vesalius, Cooper recognized the importance of the suspensory ligaments for both the prevention, and origin of ptosis when he noted that *'yet by this fibrous tissue* [the suspensory ligaments] *it is, excepting under age, lactation, or relaxation, prevented from much change of place*' (quote on p. 50, respectively p. 46) [8, 13]. He noted furthermore that *'when the period of lactation is passed, and the breast begins to be absorbed, fat is abundantly deposited, to fill up the deficiency of glandular matter, and to preserve the natural form of the part. But in very old age, both the gland and the fat become absorbed, and the chest is then flattened like that of the male'* (quote on p. 73, respectively p. 59) [8, 13]. Indeed, we currently accept that the shape of the breast will change with age as the suspensory structures become lax and the breast becomes more ptotic. Parenchymal changes with aging, weight changes, and pregnancy are also accompanied by specific alterations in the integrity of the suspensory ligaments, the breast's fascial components, and the overlying skin [6].

Conclusion

Vesalius' record of the nature and function of the *fleshy membrane* between mammary gland and pectoral muscle, the *hard fat* intervening the mammary glands, and the *fibers running from the fleshy membrane to the skin* are a clear representation of posterior layer of the SFS, the fibro-adipose stroma surrounding and linking the mammary glandular elements, and the suspensory ligaments as we know them. Thus, Vesalius recorded the anatomy and function of the latter structures nearly 300 years before Sir Astley Paston Cooper did.

Compliance with ethical standards

Conflict of interest There is no conflict of interest to be disclosed by either of the authors.

References

1. Di Fiore MSH (1974) Mammary gland, inactive and during pregnancy. In: di Fiore MSH (ed) Atlas of human histology, 4th edn. Lea Febiger, Philadelphia, pp 228–229
2. Johnson D, Shah P, Collins P, Wigley C (2008) Breast. In: Standring S (ed) Gray's anatomy: the anatomical basis of clinical practice, 39th edn. Elsevier, Chirchill Livingstone, p 974
3. Anastassiades OT, Spiliades C, Tsakraklides E, Gogas J (1983) Amount and distribution of solid and fatty tissues in the female breast and their relationship to carcinoma. Pathol Res Pract 176:200–215
4. Ramsay DT, Kent JC, Hartmann RA, Hartmann PE (2005) Anatomy of the lactating human breast redefined with ultrasound imaging. J Anat 206:525–534

5. Lockwood TE (1991) Superficial fascial system (SFS) of the trunk and extremities: a new concept. Plast Reconstr Surg 87:1009–1018
6. de la Torre JI, Davis MR (2013) Anatomy for plastic surgery of the breast. In: Neligan PC (ed) Plastic surgery: the breast, vol 5, 3rd edn. Saunders Elsevier, London, pp 1–12
7. Nickell WB, Skelton J (2005) Breast fat and fallacies: more than 100 years of anatomical fantasy. J Hum Lact 21:126–130
8. Cooper AP (1840) On the anatomy of the breast. Longman, Orme, Green, Brown, and Longmans, London
9. De Vesalius A (1998) Humani Corporis Fabrica Libri Septem, Basel, 1543. Octavo Corporation, Palo Alto CA
10. Richardson WF, Carman JB (1999) Andreas Vesalius on the fabric of the human body, book V: the organs of nutrition and generation San Francisco. Norman Publishing, CA
11. Richardson WF, Carman JB (1999) Andreas Vesalius on the fabric of the human body, book II: the ligaments and muscles. Norman, San Francisco
12. Brinkman R, Hage J (2015) Andreas Vesalius' 500th anniversary: initiation of the superficial fascial system and superficial musculoaponeurotic system concepts. Ann Plast Surg 76:138–142
13. Cooper AP (1845) The anatomy and diseases of the breast. Lea Blanchard, Philadelphia
14. Gardner E, Gray DJ, O'Rahilly R (1975) Veins, lymphatic drainage, and breast. In: Gardner E, Gray DJ, O'Rahilly R (eds) Anatomy: a regional study of human structure. Saunders, Philadelphia, pp 98–103
15. Vesalius A (1543) *De Fabrica Corporis Humani Libri Septem*. 1st ed, Oporinus, Basel