The Blood Supply of the Breast Revisited

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Background: Many surgeons are under the impression that the blood supply is clearly defined in textbooks. Unfortunately, the majority of textbooks supply inadequate information and illustrations can be misleading in many instances. None of the textbooks describe a segmental pattern of blood supply when in actual fact a basic segmental pattern does exist. The reason for inadequate information is the perpetuation of facts since the work of the pioneers Cooper and Manchot from one textbook to another. A paucity of research studies thereafter and the fact that the results of some of these studies did not find their way into textbooks is another contributing factor.

Methods: The findings of research studies since the descriptions by Cooper and Manchot are analyzed and compared in an effort to find common ground and its clinical implication.

Results: Researchers concurred on the main sources of blood supply; these are internal thoracic, lateral thoracic, anterior intercostal, and acromiothoracic (thoracoacromial) arteries. However, the different research studies showed considerable variation in the branches from the main sources to supply the nipple-areola complex.

Conclusions: Even though the locations of the main sources of blood supply are constant, partial or complete absence of branches from the main sources does occur and therefore the blood supply to the nipple-areola complex is unpredictable. Cognizance of the basic segmental pattern and the variations resulting from embryologic development will be helpful for the surgeon to use or adapt a technique to minimize the risk of nipple necrosis. (*Plast. Reconstr. Surg.* 137: 1388, 2016.)

Many plastic surgeons are under the impression that the blood supply to the breast is clearly described in textbooks. Unfortunately, the majority of textbooks supply inadequate information in this regard, and illustrations are frequently misleading. For instance, the majority of plastic surgery textbooks illustrate a radial pattern of blood supply to the nipple-areola complex. This is found in only 6 percent of breasts according to the research by Marcus.[1] Illustrations of the blood supply in textbooks made by artists for publication purposes without taking into consideration the existing data as supplied by previous research studies may lead to misrepresentation of the true facts. None of the textbook illustrations reveals a segmental pattern of blood supply, which in actual fact does exist.

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A reason for inadequate information can be the perpetuation of facts from one textbook to the other since the works of the pioneers Cooper[2]

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and Manchot.[3] These pioneers described the main sources, but the variation in the different patterns of blood supply to the nipple-areola complex were not described in detail, most probably because of limited breast dissections. If the information supplied by plastic surgery textbooks is relied on, there is a real risk of nipple necrosis in some cases, even in the hands of the most competent and experienced plastic surgeon.

It is very difficult to obtain suitable adult female cadavers for research, with the result that since the classic description of the blood supply to the breast by Cooper and Manchot, there has been a paucity of research studies. Würinger et al. dissected 28 breasts[4,5]; van Deventer, 27 breasts[6]; Marcus, 23 breasts[1]; O'Dey et al., 14 breasts[7]; Salmon, 14 breasts[8]; Nakajima et al., 10 breasts[9]; Anson et al., eight breasts[10]; Carr et al., eight breasts[11]; and Michelle le Roux et al., seven breasts.[12]

Radiographic studies conducted by Palmer and Taylor[13] on 31 fresh cadavers were not concerned specifically with the blood supply to the breast and nipple-areola complex but investigated the vascular architecture of the chest wall. This excellent study, however, improves our understanding of the anastomoses between the major sources within the thoracic wall and the location of their perforating branches, some of which supply the breast.

The basic principle that adult anatomy is the result of embryonic development is applicable to the vascularity of the breast as well. Taking this into account, it must be expected that the blood supply to the breast should be similar to the segmental pattern of the thoracic wall. To test this theory, the first author[6] conducted a research project, dissecting 27 adult cadaver breasts injected with latex, and a basic underlying segmental pattern of blood supply could be demonstrated. (**See Video, Supplemental Digital Content 1**, which shows the blood supply of the breast, ***http://links.lww.com/PRS/B682***.)

Video. Supplemental Digital Content 1 shows the blood supply of the breast, ***http://links.lww.com/PRS/B682***.

However, this is not mentioned by previous investigators or textbooks. Instead, considerable variations in the pattern of the blood supply to the breast are described. A possible explanation for this variation in blood supply would be that the nutritional requirements of the developing milk ridge cause a change in the development of the vascular system in that area. Understandably, the blood supply to the breast has clear clinical implications in breast reduction, mastopexy, augmentation mammaplasty, and breast reconstruction procedures.

METHODS

The findings of the different research studies since the descriptions by Cooper and Manchot are analyzed and compared in an effort to find common ground and to determine the clinical application.

RESULTS

Researchers concurred on the main sources of blood supply to the breast; these are the internal thoracic (mammary), lateral thoracic, anterior intercostal, and acromiothoracic (thoracoacromial) arteries. The posterior intercostal, superficial thoracic, superior intercostal (highest intercostal), and highest thoracic arteries are of less importance.

Different research studies showed considerable variation in the branches from the main sources supplying the nipple-areola complex. To be aware of the possible variations, it is essential to consider the results of the different research studies.

Main Sources

Internal Thoracic (Internal Mammary) Artery

According to Manchot, the internal thoracic artery supplies the breast with six or seven perforating branches, of which the second was considered the principal one. Marcus reported perforating branches from the upper four intercostal spaces, most frequently from the second intercostal space, less from the third space, and the least from the first and fourth spaces.

Research by van Deventer revealed that the internal thoracic artery is the most constant and reliable main source (Fig. 1). The perforating branches of the upper four intercostal spaces supply the breast and one or more arteries always reached the nipple-areola complex. These vessels formed anastomoses with branches from the lateral

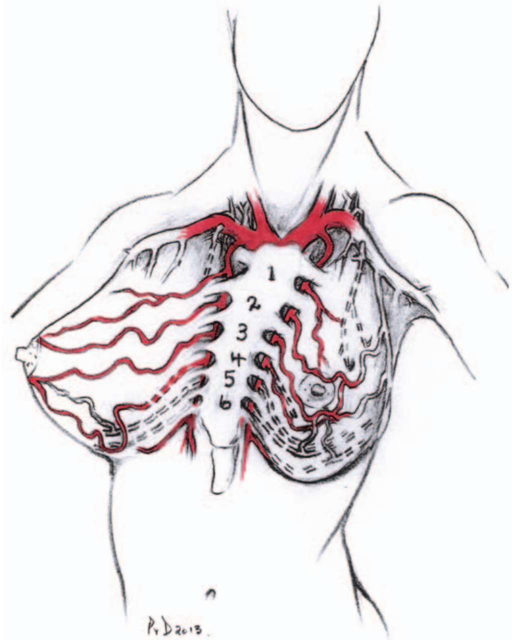

Fig. 1. Blood supply of the breast by means of the perforating branches of the internal thoracic artery. Note the segmental pattern as a result of the anastomoses with the lateral thoracic artery.

thoracic artery. The most frequently found was the third perforator, followed by the second, the first, and the fourth. Anastomoses between adjacent perforators in the periareolar area were found as well, possibly enhancing the blood supply to the nipple-areola complex.

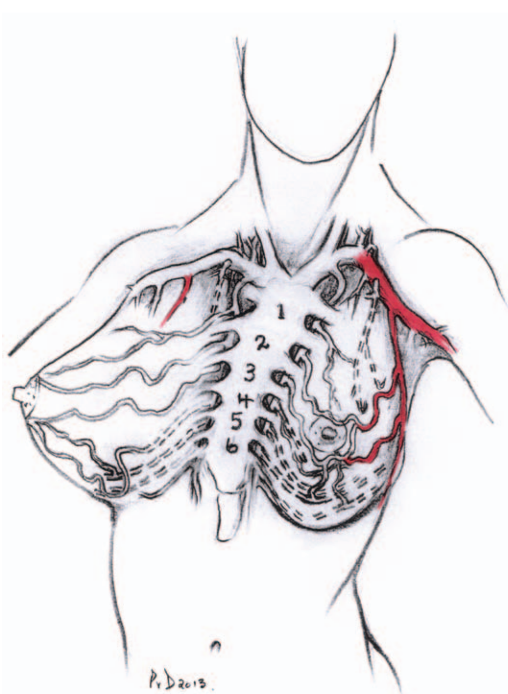

Fig. 2. Blood supply of the breast from the lateral thoracic artery.

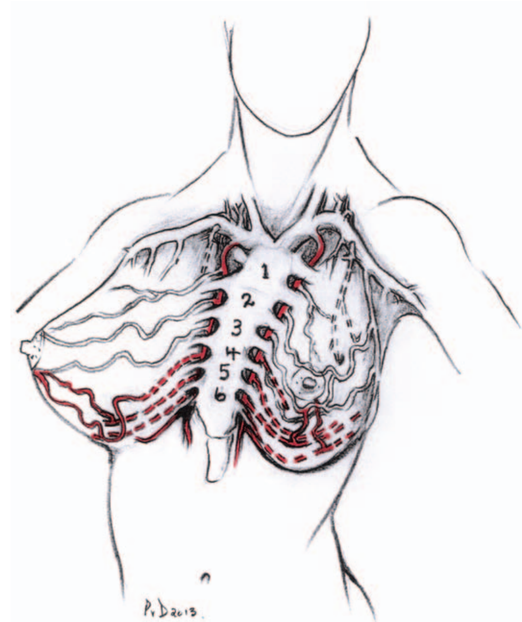

Fig. 3. Blood supply of the breast from the fourth to the sixth anterior intercostal arteries. Anastomoses of these branches with the perforators of the internal or lateral thoracic artery can change the horizontal segmental pattern of supply to the nipple-areola complex.

Carr et al. reported a constant supply from the perforators of the internal mammary (internal thoracic) artery from the first through the fourth interspaces. The most frequent was the second interspace, followed in decreasing order by the first, third, and fourth.

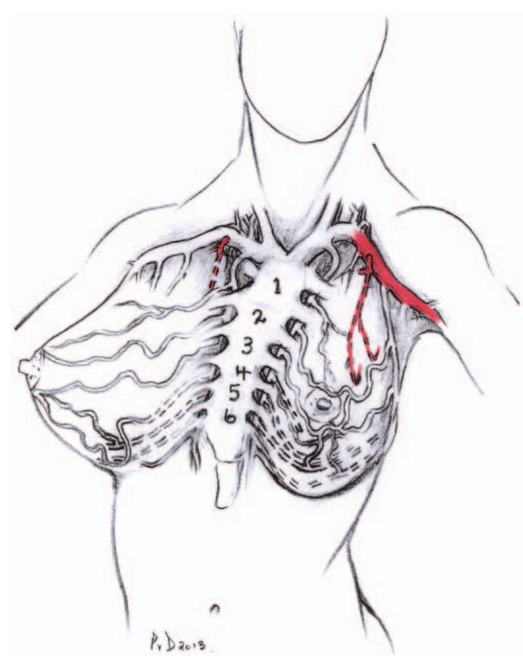

Fig. 4. Blood supply to the breast from the acromiothoracic (thoracoacromial) artery.

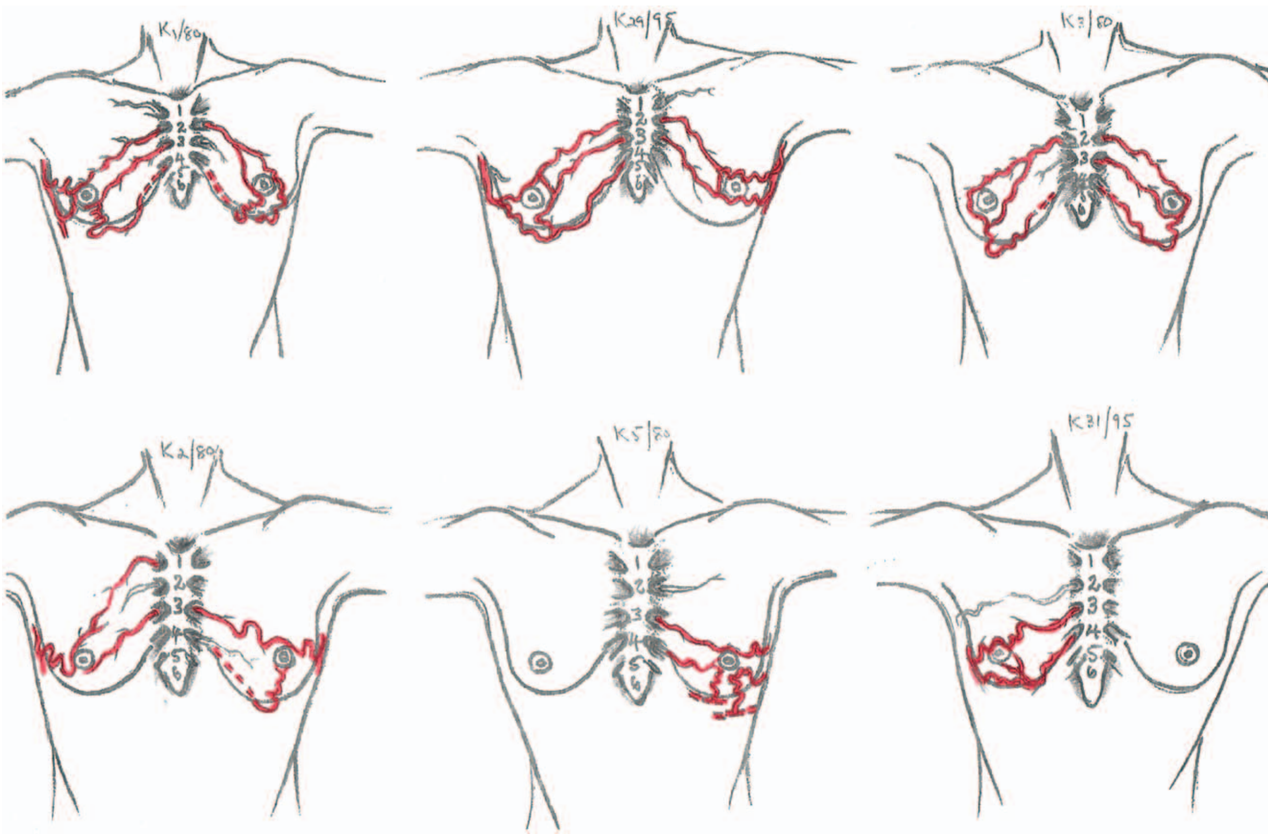

Fig. 5. Dissections by van Deventer demonstrating the variation in the pattern of blood supply to the breast. Note abundant anastomoses between the perforators of the internal thoracic artery, with branches of the lateral thoracic artery resulting in a basic segmental pattern of blood supply to the nipple-areola complex.

Michelle le Roux et al.[12] have demonstrated that the perforators of the internal thoracic artery run in a superficial plane an average of 1 cm under the skin surface. A dominant vessel originates from either the third or the fourth intercostal space with a depth of 10.3 mm at the nipple-areola complex boundary and 14.2 mm at 3 cm medially.

According to O'Dey et al., the contribution of the internal thoracic artery is by means of the second and fourth perforators.

Würinger et al. demonstrated the perforating branches of the internal thoracic artery originating from the second, third, and fourth intercostal spaces running within the medial vertical ligament of the breast toward the nipple.

Anson et al. found five perforating arteries from the internal mammary (internal thoracic) artery, each corresponding to each of the upper five intercostal spaces.

Palmer and Taylor, in a series of 31 fresh cadaver injections with radiographic and dissection studies, confirmed that the dominant supply to the vascular architecture of the anterior chest wall is from the internal thoracic artery.

Lateral Thoracic (External Mammary) Artery

Manchot and Marcus reported the lateral thoracic artery in a varying relationship with the internal mammary (internal thoracic) artery. According to Marcus, the lateral thoracic artery, by means of two different branches, forms anastomoses with the upper branches of the internal thoracic artery above the nipple and lateral branches, anastomosing below the nipple with branches of the internal thoracic artery.

The study by van Deventer revealed that the lateral thoracic artery supplied the nipple-areola complex with one or two branches, frequently anastomosing with the perforating branches of the internal thoracic artery above and below the nipple (Fig. 2).

O'Dey et al. reported three branches from the lateral thoracic artery to supply the nipple-areola complex, with an average diameter of 1.5 ± 0.3 mm.

Carr et al. reported an absence of branches from the lateral thoracic artery in three of eight dissections.

Würinger et al. reported branches from the lateral thoracic artery arising at the level of the second, third, and fourth intercostal spaces,

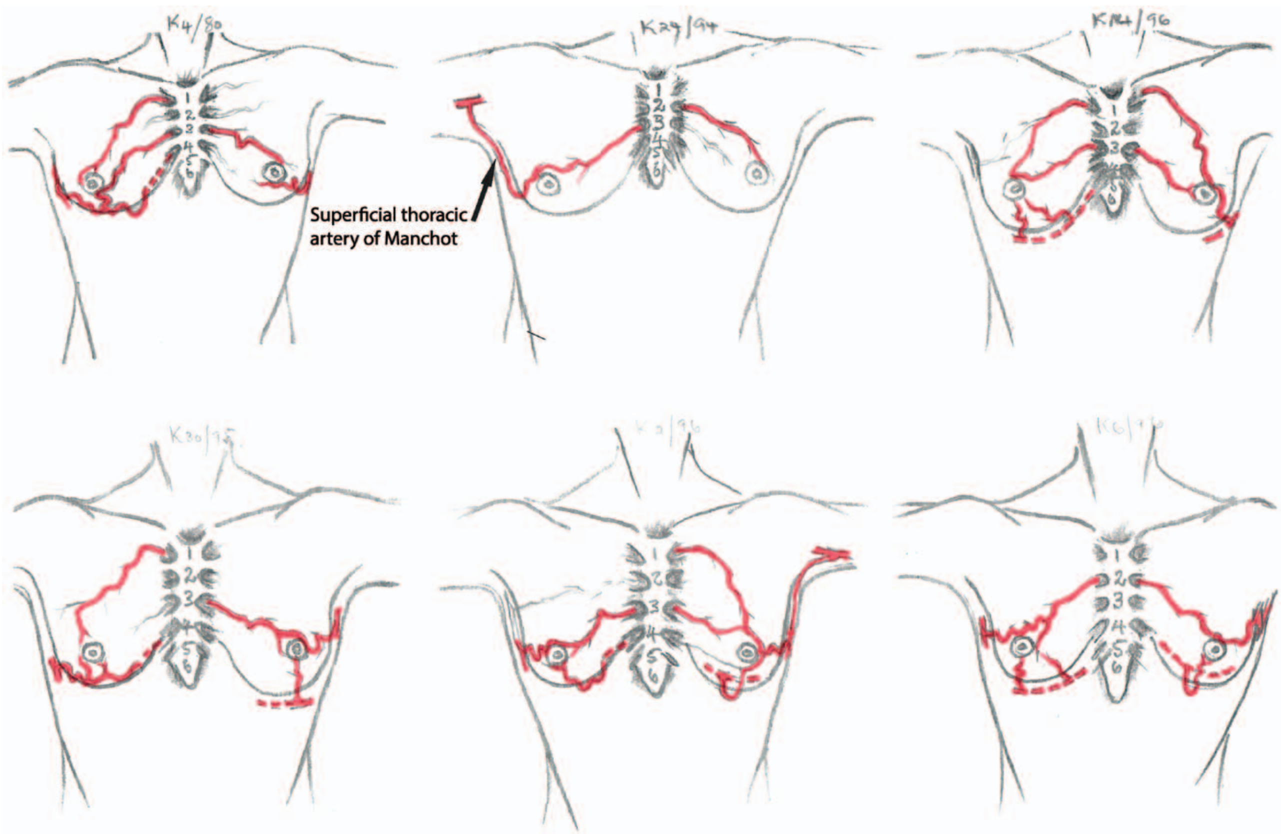

Fig. 6. Dissections of female cadaver breasts by van Deventer demonstrating the variation in the pattern of blood supply to the nipple-areola complex. Note the absence of branches from the anterior intercostal arteries in cadaver K29/94 and the absence of branches from the lateral thoracic artery reaching the nipple-areola complex in cadaver K14/96. The nipple-areola complex is supplied by perforators of the internal thoracic in all instances.

running within the lateral vertical ligament of the breast toward the nipple.

Anson et al. described anastomosis between the lateral thoracic artery and cutaneous perforators of the internal mammary (internal thoracic) artery.

According to anatomy textbooks, the lateral thoracic artery originates from the axillary artery. However, research by Loukas et al.[14] revealed that this is the case in only 17.02 percent of cadaver dissections, and in 67.62 percent it originates from the thoracoacromial artery. Their research also revealed complete absence of the lateral thoracic artery of 3.33 percent.

Anterior Intercostal Arteries

Marcus described one to three branches from the intercostal arteries from the third to fifth intercostal spaces supplying the lower inner quadrant of the breast.

According to the study by the first author (P.V.D.), the anterior intercostal arteries supply the nipple-areola complex with branches from the fourth to sixth intercostal spaces (Fig. 3). The most important was the branch from the fourth intercostal artery, usually perforating the chest wall at the fourth costochondral junction.

O'Dey et al. observed branches from the fourth and fifth intercostal spaces with a caliber of 1.2 ± 0.2 mm.

Würinger et al. described cutaneous perforating branches from the fourth, fifth, and rarely sixth intercostal arteries running within the caudal layer of the horizontal septum of the breast toward the nipple.

Salmon considered inner intercostal arteries as posterior branches of the internal mammary (thoracic) artery penetrating the fourth and fifth intercostal spaces to supply the breast.

Palmer and Taylor, investigating the vascular supply of the anterior chest wall, demonstrated the concentration of large perforators that exist along the inframammary crease arising from the anterior intercostal vessels in the fifth and sixth intercostal spaces.

Acromiothoracic (Thoracoacromial) Artery

Würinger et al. have shown with intraarterial injection of surgical ink in the thoracoacromial artery a slight coloration of the periareolar skin.

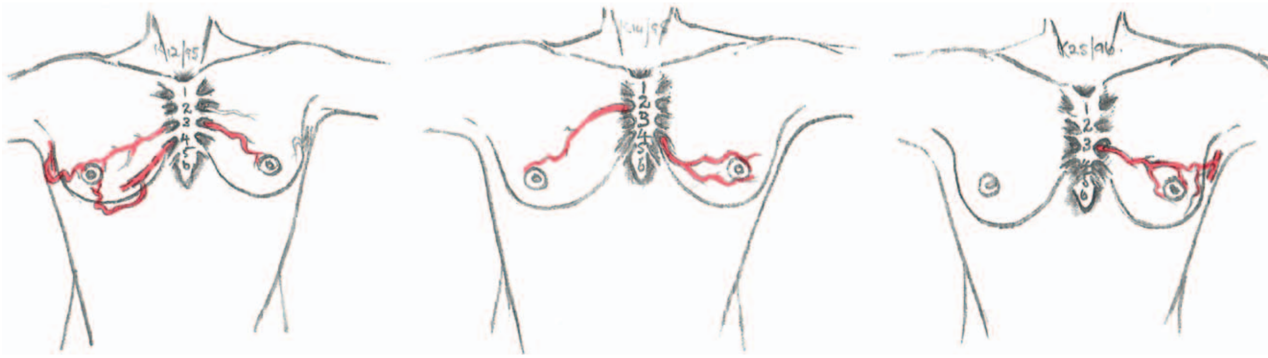

Fig. 7. Female cadaver breasts dissections by van Deventer demonstrating absence of the lateral thoracic artery in specimen K14/98 and absence of branches from the anterior intercostal arteries to supply the nipple-areola complex in cadavers K25/96, K14/98, and the left breast of K12/95.

Reid and Taylor,[15] examining the territory of the acromiothoracic axis, found the dominant supply to the skin arising along the free lower border of the pectoralis major muscle.

Loukas et al.[14] found that the lateral thoracic artery originates from the thoracoacromial artery in 67.62 percent of cadaver dissections. This artery therefore must be considered an important main source of blood supply to the breast (Fig. 4).

Posterior Intercostal Arteries

Although described in many plastic surgery textbooks as an important contributor to the blood supply to the breast, research studies did not confirm this. According to the study by the first author, it only contributes to supply the nipple-areola complex in one of 27 dissected breasts.

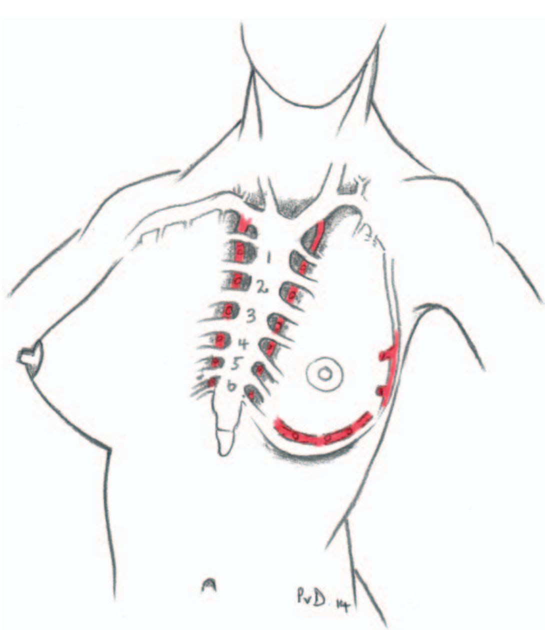

Fig. 8. Illustration of the hypervascular zones (fixed skin areas) of the thoracic wall as described by Palmer and Taylor.

Superficial Thoracic Artery

This artery was described by Manchot and is not identical to the lateral thoracic artery. It also runs along the lateral border of the pectoralis minor muscle and supplies the nipple with multiple branches.

Highest Thoracic Artery or Superior (Highest) Intercostal Artery

O'Dey et al. described the highest (superior) thoracic artery supplying the nipple. The artery they described may well be the superior (highest) intercostal artery.

Anastomoses between Major Sources

Marcus described three different plexuses as a result of the anastomoses between the major sources. A circular periareolar plexus formed between the internal thoracic and lateral thoracic arteries, and a frequency of 74 percent and dominance of the internal thoracic artery. A loop type plexus was found between the internal thoracic and lateral thoracic arteries, with dominance of the lateral thoracic artery at a frequency of 20 percent. The third is a radial type pattern in 6 percent of breasts examined, with contributions of internal thoracic, lateral thoracic, and intercostal arteries and with ramifications from these sources directed toward the nipple.

The study by van Deventer revealed an incidence of 50 percent in the anastomoses between the internal thoracic and lateral thoracic arteries, 29 percent between the internal thoracic and anterior intercostal arteries, 14 percent between the anterior intercostal and lateral thoracic arteries, and less between the other sources (Figs. 5 through 7). The fact that the anastomoses between internal thoracic and lateral thoracic arteries is the most abundant is an indication of the segmental pattern of blood supply to the breast.

Hypervascular and Hypovascular Zones

Palmer and Taylor identified fixed skin areas around the perimeter of the pectoralis major muscle, the costal margin, and the lateral chest wall overlying the interdigitations of the serratus anterior muscle (Fig. 8). Major cutaneous perforators emerged in these areas, referred to as hypervascular zones.

In contrast, vessels emerging from the anterior surface of the pectoralis major muscle are few and generally of a very small caliber. This area is referred to as a hypovascular plane.

DISCUSSION

The main sources of blood supply to the breast are the internal thoracic, lateral thoracic, anterior intercostal, and acromiothoracic arteries (Fig. 9). The internal thoracic perforators are found to be the most reliable by most researchers.

A basic segmental supply pattern exists that can be distorted to a lesser or greater extent by vertically oriented vessels and a variety of different anastomoses. This distortion may be regarded as the result of embryologic development, and the adult vasculature of the breast can present with partial or total absence of certain branches from the main sources. Therefore, the blood supply to the nipple-areola complex is unpredictable. However, the areas where these vessels emerge through the thoracic wall (hypervascular zones/fixed skin areas) are constant and include the parasternal border, submammary fold, and the lateral thoracic wall along the lower lateral border of the pectoralis minor muscle (Fig. 8).

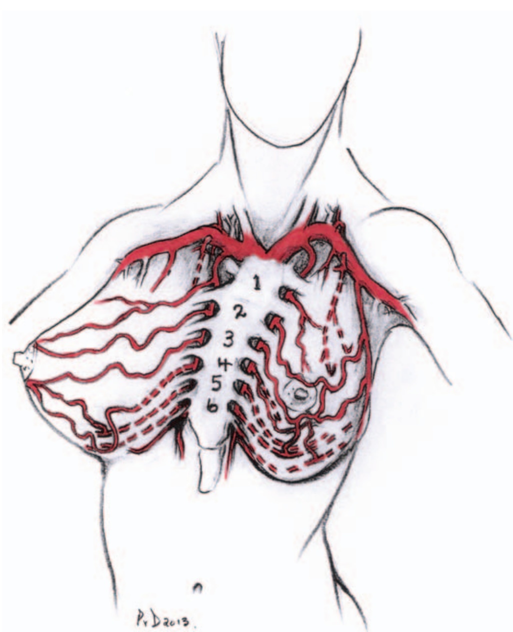

Fig. 9. Research by van Deventer revealed 50 percent anastomoses between the perforators of the internal thoracic and lateral thoracic arteries, resulting in a basic horizontal segmental pattern of blood supply to the nipple-areola complex.

Clinical Application

Even though the locations of the main sources of blood supply are constant, partial or complete absence of branches from the main sources do occur, and therefore it is impossible for the surgeon to predict the blood supply to the nipple-areola

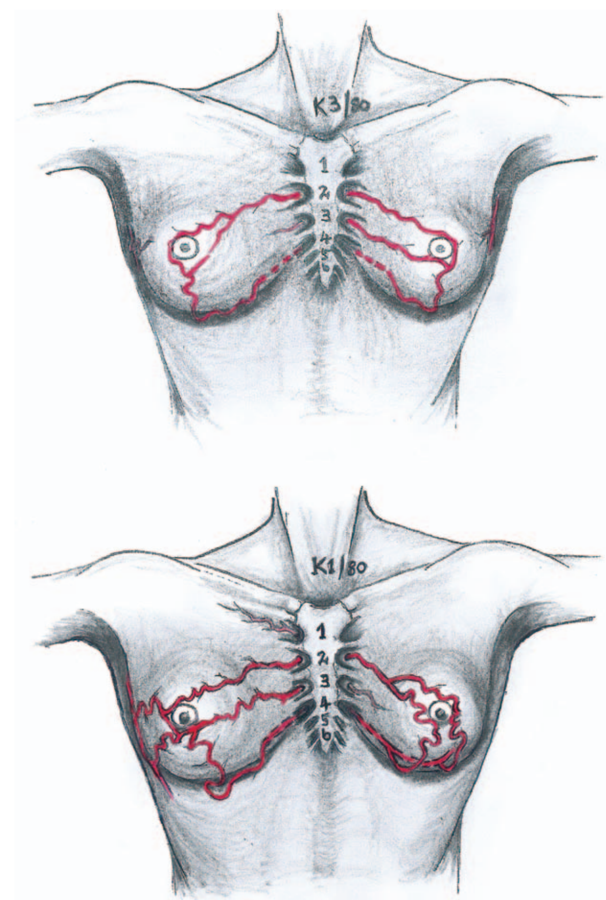

Fig. 10. Cadaver K3/80 demonstrates underdevelopment of branches from the lateral thoracic artery in the right breast resulting in a change of the segmental horizontal pattern of the blood supply into a ring anastomosis supplying the nipple-areola complex. Total absence of branches from the lateral thoracic artery in the left breast of cadaver K1/80 resulted in a robust supply from the anterior intercostal arteries anastomosing with perforators of the internal thoracic artery, changing the horizontal pattern into an oblique vertical one.

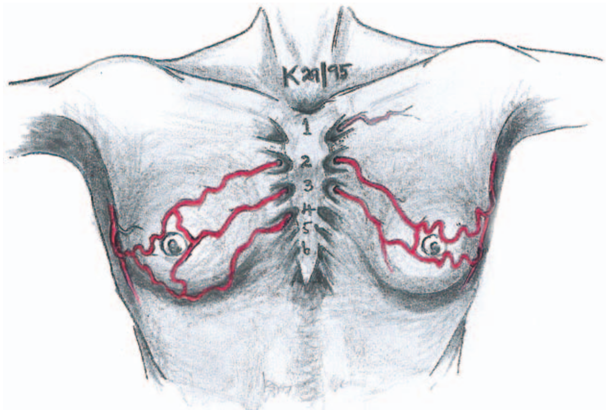

Fig. 11. The left breast of cadaver K29/95 demonstrates the absence of branches from the anterior intercostal arteries to supply the nipple-areola complex.

complex of the specific breast operated on. Van Deventer found that in seven of 27 breast dissections, branches from the lateral thoracic artery did not supply the nipple-areola complex (Figs. 7 and 10), and that in eight breasts, branches from the anterior intercostal arteries were absent (Figs. 6 and 11). However, in all of the dissected breasts, the nipple-areola complex received one or more perforating branches from the internal thoracic artery (Figs. 5 through 7 and 9).

Cognizance of the basic segmental pattern and the variations resulting from embryologic development will be helpful for the surgeon to use or adapt his or her technique to minimize the complication of nipple necrosis. Once the surgeon realizes the basic segmental pattern of blood supply between the internal and lateral thoracic arteries, with an inferior contribution from the anterior intercostal arteries, it is easier to understand the possible variations that can occur. In designing a pedicle, certain arteries must be relied on, whereas others can be sacrificed (Table 1).

Table 1. Arteries That Can Be Relied on and Those That Can Be Sacrificed

Pedicle	Technique	Arteries Relied On	Arteries Sacrificed
Superior	Wiener	Internal thoracic perforators 1 and 2 (in the very ptotic breast), acromiothoracic	Anterior intercostals, lateral thoracic, internal thoracic perforators 3–5
Inferior	Courtiss/Robbins	Anterior intercostal	Internal thoracic perforators, lateral thoracic, acromiothoracic
Medial	Finger	Internal thoracic perforators 2 and 3	Anterior intercostal, lateral thoracic, acromiothoracic
Lateral	Skoog	Lateral thoracic	Anterior intercostals, internal thoracic perforators, acromiothoracic
Posterior/central	Balch	Anterior intercostals, nipple-areola branches of internal thoracic (Salmon's posterior mammary arteries)	Internal thoracic perforators, lateral thoracic
Superomedial	Finger	Internal thoracic perforators	Lateral thoracic, anterior intercostals, acromiothoracic
Horizontal bipedicle	Strombeck	Internal thoracic perforators, lateral thoracic	Anterior intercostals, acromiothoracic
Vertical bipedicle	McKissock	Anterior intercostal, acromiothoracic, internal thoracic perforators 1 and 2 in the very ptotic breast, nipple-areola branches of internal thoracic (Salmon's posterior intercostal arteries)	Lateral thoracic, internal thoracic perforators 3–5
Posteroinferomedial retaining the medial vertical ligament of Würinger	van Deventer	Anterior intercostals, internal thoracic perforators 1–4, nipple-areola branches of internal thoracic: usually fourth intercostal space (Salmon's posterior mammary arteries)	Lateral thoracic, acromiothoracic
Septum based with lateral pedicle	Hamdi	Lateral thoracic, anterior intercostals, nipple-areola branches of internal thoracic (Salmon's posterior mammary arteries)	Internal thoracic perforators
Septum based with medial pedicle	Hamdi	Internal thoracic perforators 1–4, anterior intercostal, nipple-areola branches of internal thoracic (Salmon's posterior mammary arteries)	Lateral thoracic, acromiothoracic
Inferior hemicircumareolar	Würinger	Anterior intercostals, internal thoracic perforators, lateral thoracic, nipple-areola branches of internal thoracic (Salmon's posterior mammary arteries)	
Superior hemicircumareolar	Pitanguy	Internal thoracic perforators, superficial thoracic artery of Manchot, superior branch of lateral thoracic	Anterior intercostal, nipple-areola branches of internal thoracic (Salmon's posterior mammary arteries)

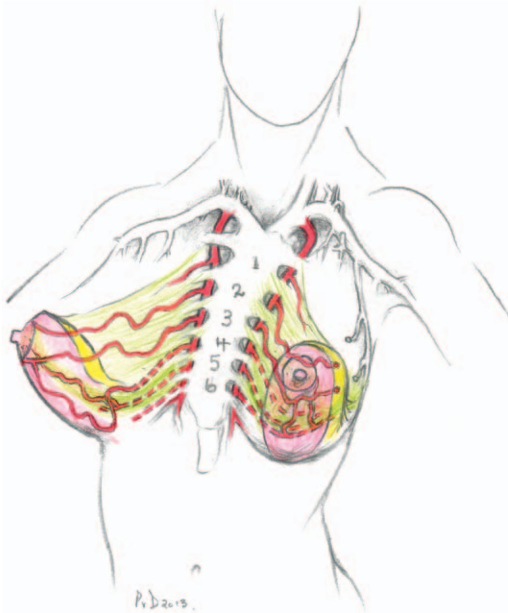

Fig. 12. Illustration of the posterior inferomedial pedicle retaining the medial vertical ligament enhancing the blood supply to the nipple-areola complex with its dual blood supply, namely, the perforators of the internal thoracic artery in the medial vertical ligament and the branches of the anterior intercostal arteries in the horizontal septum.

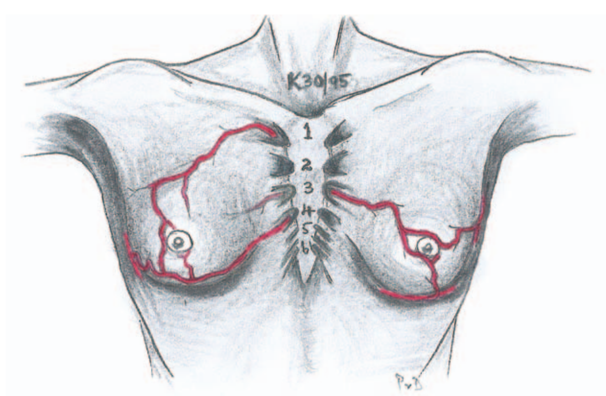

Fig. 13. In cadaver K30/95, internal thoracic perforators 1 and 4 supply the nipple-areola complex in the right breast, with absence of the second and underdevelopment of the third perforator. If a superomedial pedicle with a narrow base is used, it will not be arterialized. In the left breast, superomedial, superolateral, and inferior pedicles will be arterialized, despite absence of perforators 1, 2, and 4.

Using a technique to include branches from more than one main source will be safer. In inferior pedicle techniques, this can be obtained by preserving the horizontal septum and medial vertical ligament as described by van Deventer and Graewe[16,17] (Fig. 12). The advantage of this technique is the reliability of the perforators of the internal thoracic artery in the retained medial vertical ligament combined with the branches of the anterior intercostal arteries in the horizontal septum with a dual blood supply in the pedicle.

The lateral vertical ligament can also be retained with the horizontal septum as described by Hamdi et al.[18] The advantage of this technique is the short pedicle and a dual blood supply in the pedicle, namely, the branches of the lateral thoracic and the anterior intercostal arteries.

With superomedial pedicle techniques, the base of the pedicle should be wide enough to preserve the upper four perforators of the internal thoracic artery, ensuring arterialization of the pedicle[19] (Fig. 13). Nipple necrosis seen in the transverse pedicle technique (Strombeck) may be the result of a too narrow medial component. In contrast, nipple necrosis can occur as a result of venous congestion because of a very thick pedicle with compression of the venous outflow. The perforator branches from the internal thoracic artery travel beneath the skin surface 1 to 1.5 cm and can be taken into consideration in creating a pedicle. A broad, relatively thin pedicle would be safer to use.

This analysis of the blood supply to the breast is concentrated on the arterial supply and has not addressed the venous return as a separate entity. However, necrosis of the nipple-areola complex or fat necrosis following breast surgery can also be caused by venous congestion. Venous drainage networks in the breast must also be considered and care taken to avoid damaging the superficial network of veins. If there is any doubt intraoperatively regarding the survival of the nipple-areola complex, it would be wise to consider converting to a free nipple graft procedure instead of the pedicle technique.

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