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Case Reports
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Dealing with vascular anomalies during radial forearm free flap harvest: report of two cases and review of the literature

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Abstract. Radial forearm free flap reconstruction for head and neck cancer is very common, and it is widely considered a workhorse flap. Although this flap has a relatively reliable anatomy, surgeons need to be aware of possible anatomical variations and how to deal with them. This paper presents the cases of two patients who underwent oral reconstruction, in whom anomalies of the radial artery were identified while raising a radial forearm free flap. Case 1 demonstrates the dominant branch of the radial artery joining the common interosseous artery approximately 9 cm from the first wrist crease. Case 2 demonstrates abnormal distal branching of the radial artery approximately 4 cm from the first wrist crease. Reconstruction with the flap was successful in both cases. A literature review of reported anomalies of the radial artery is presented, and how to deal with such vascular anomalies is discussed.

Key words: radial forearm; radial artery; anomalies; aberrant radial artery.

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The fasciocutaneous radial forearm free flap was first described in 1981 by Yang et al.[1], and became widely known as the 'Chinese flap'. It has become the workhorse free flap for oral reconstruction due to its vascular and anatomical reliability, pliability, and ability to transfer as a composite flap.

Understanding the arterial blood supply to the hand starts with a good understanding of the embryology. At 26 days of foetal development, the upper limb vascular bud initiates its outgrowth and consists at this stage of dispersed capillary networks within the developing upper limb, before differentiation of any skeletal or muscular elements[2]. By day 44 in the developing foetus, the humerus, ulna, and radius are chondrified, and the vascular pattern is more differentiated, with the ulnar artery and median artery together with the anterior interosseous artery forming the main arterial supply to the hand[2]. At this stage, the future radial artery is still in a capillary state with an undifferentiated arterial wall. By the end of the second embryonic month, the medial artery regresses in the majority of cases, leaving the ulnar and radial arteries to provide the main arterial supply to the hand. The anatomical variations in adults result from persistence, enlargement, and differentiation of parts of these initial networks, which would

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normally remain as capillaries or even regress.

In the majority of adults, the brachial artery divides into ulnar and radial arteries, which supply the arterial arches of the hand. From a reconstructive perspective, the skin of the forearm is vascularized through septocutaneous and musculocutaneous perforators of the radial and ulnar arteries, and microvascular free flaps can be designed around these main arterial systems[3]. The most common arterial variation is persistence of the median artery. If the regression of the median artery occurs late, the median artery may persist, running parallel to the median nerve in the carpal tunnel[3]. The median artery is present in approximately 8–10% of the population, with the incidence varying in different populations[4,5].

Although the arterial pattern of the arm is regarded as fairly constant, the anatomy of the superficial venous system is highly variable[6]. Anomalies in the deep venae comitantes of the radial artery have not been investigated as much, and the microvascular surgeon must be mindful of the path of the venae comitantes while harvesting the radial forearm free flap to ensure adequate venous drainage of the flap.

Due to the high reliability of the arterial system, preoperative imaging of the arterial system is regarded unnecessary when there is a normal Allen's test result[7]. However, anomalies of the radial artery do occur, and although uncommon, should be understood by the surgeon to ensure safe harvest of the radial forearm free flap in all situations. In a study of 750 cadaver extremities, McCormack et al. described anatomical variations in the radial artery in 4.3% of cases[8]. In another study of 100 upper extremity arteriograms, Uglietta and Kadir found an overall incidence of radial artery anomalies of 9%[9]. The most frequently occurring anomaly was a high origin of the radial artery from the brachial artery. Other reported anomalies may be developmental abnormalities during embryogenesis. Aplasia and hypoplasia of the radial artery have been reported in association with several congenital malformations such as Klippel–Feil syndrome, VATER association, and trisomy 21 (Down syndrome)[10,11].

In this paper, the cases of two patients with vascular anomalies identified during radial forearm free flap harvest are described. Case 1 demonstrates a dominant radial artery branch passing deep to the pronator teres before joining the interosseous artery, with the venae comitantes following the smaller radial artery with a high take off at the brachial artery. Case 2 demonstrates early bifurcation of the distal radial artery into the superficial and deep palmar branches approximately 4 cm proximal to the first wrist crease.

Case reports

Case 1

A 63-year-old female presented with a T1N0M0 squamous cell carcinoma of the soft palate. She was staged and planned for a wide local excision with 1-cm macroscopic margins, neck dissection, and reconstruction. A left radial forearm free flap was planned to reconstruct the defect.

The left (non-dominant) arm was chosen and an Allen's test was performed prior to harvesting to confirm adequate ulnar supply to the hand. The radial forearm flap was marked for a skin paddle measuring 6 cm × 5 cm in a conventional manner, planning to incorporate the radial artery within the centre of the skin paddle. A tourniquet was applied after minimal exsanguination and set to 250 mmHg throughout the dissection. The ulnar dissection was commenced first with a subfascial dissection performed until reaching the tendon of the flexor carpi radialis (FCR). Subsequently a radial dissection was performed incorporating the cephalic vein in the flap down to the brachioradialis (BR) muscle. Subfascial radial dissection was then performed until the tendon of the brachioradialis was identified. The radial artery and its venae comitantes were then identified and tied off.

An incision was then performed to the antecubital fossa. The cephalic vein was followed and once the main cephalic vein had been followed to the antecubital fossa, any obvious side branches were then ligated. The pedicle was dissected from distal to proximal, elevating the flap subfascially between the tendons of the FCR and the BR. The pedicle was followed between the muscle bellies and any muscular branches were ligated as they were found. During this stage, one of the muscular branches in the mid forearm (9 cm from the first wrist crease) was noted to be a large artery travelling deep to the pronator teres muscle. This was not ligated until the rest of the pedicle was identified. The traditional pedicle between the FCR and BR was exposed and it was noted that the artery within this pedicle was smaller than the larger branch of the radial artery travelling deep to the pronator teres; however it contained normal sized venae comitantes. The deep branch did not have associated venae comitantes. In addition, the traditional pedicle was found not to join the brachial artery but rather travelled proximal to the antecubital fossa, likely to join the brachial artery above the level of the elbow. The deep larger branch was then followed and the pronator teres was divided to expose this branch. This branch was found to join the common interosseous artery (Figs 1 and 2). The median nerve was on the ulnar surface to the common interosseous artery.

The tourniquet was released, and it was decided that the deeper branch of the radial artery would be used as the main arterial pedicle for the flap. This was divided before entering the common interosseous artery. The venae comitantes of the traditional pedicle were taken as well as the cephalic vein for venous drainage of the flap, and the smaller radial artery within the traditional pedicle was ligated.

The micro-anastomosis was then performed between the radial artery and the facial artery with an end-to-end tech-

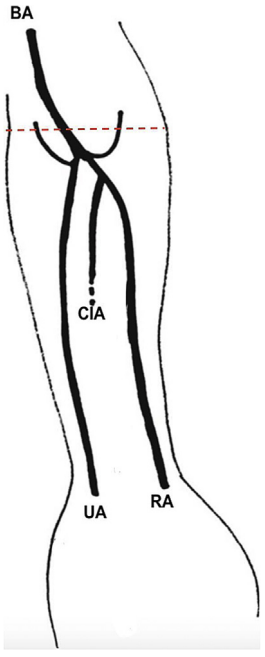

Fig. 1. Diagrammatic representation of normal radial forearm branching of the brachial artery. BA, brachial artery; UA, ulnar artery; RA, radial artery; CIA, common interosseous artery. The red dotted line indicates the antecubital fossa.

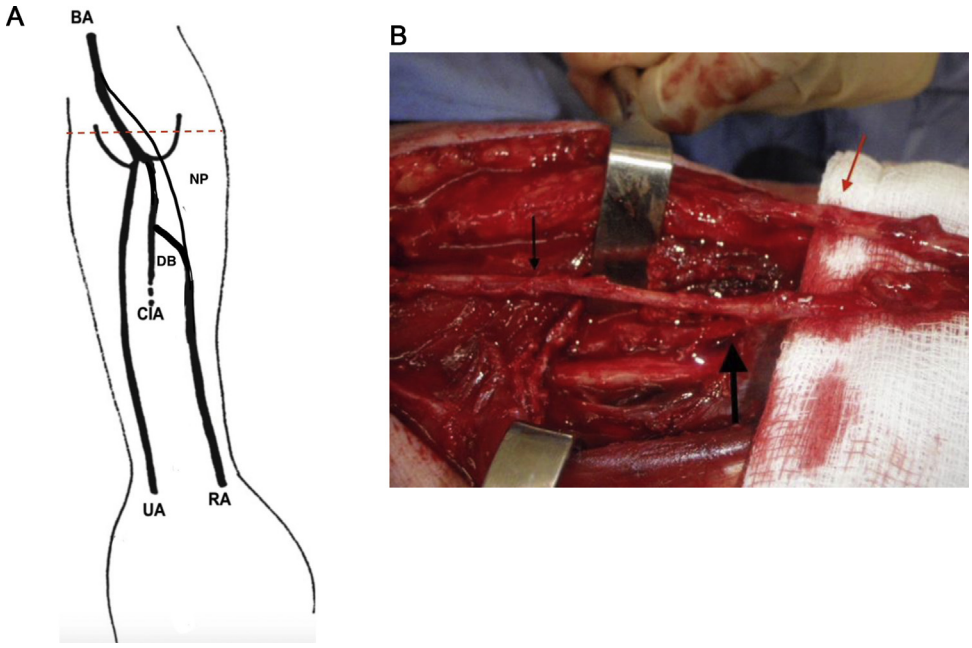

Fig. 2. (A) Diagrammatic representation of the aberrant radial artery in case 1. The dominant branch of the radial artery (DB) joined the common interosseous artery (CIA) 9 cm from the first wrist crease. BA, brachial artery; UA, ulnar artery; RA, radial artery; NP, Normal pedicle artery. The red dotted line indicates the antecubital fossa. (B) Intraoperative photograph demonstrating the anomalous radial artery. The dominant branch of the radial artery (thick black arrow) joined the common interosseous artery deep to the pronator teres muscle (retracted by the Langenbeck retractor). The traditional radial pedicle was much smaller (thin black arrow), but contained the venae comitantes. The cephalic vein (thin red arrow) was also harvested for additional venous drainage to the flap.

nique, and the cephalic vein and one of the venae comitantes were anastomosed to the internal jugular vein with end-to-side anastomoses. Adequate flap perfusion and drainage were confirmed. There were no issues with flap perfusion postoperatively. The patient made an uneventful recovery.

Case 2

A 61-year-old male presented with a right posterior maxillary ameloblastoma. He was planned for a posterior maxillectomy, right neck access procedure, and radial forearm free flap reconstruction. During the Allen test, it was noted that an easily palpable artery branching off the radial artery was crossing the dorsal aspect of the forearm to the anatomical snuff box. That branch was palpated to originate approximately 4 cm proximal to the first wrist crease. A palpable pulse was also noted in the traditional location between the FCR and BR on that side.

A 5 cm × 5 cm skin paddle was marked in the traditional way, and the tourniquet was inflated to 250 mmHg. The dissection commenced from the ulnar side in the subfascial plane as described above. When the radial dissection had been performed, the cephalic vein was located and further subcutaneous dissection was performed to delineate the additional radial branch more dorsally. The superficial radial nerve was found to be travelling superficial to the dorsal artery. The forearm was then opened proximally to follow that aberrant branch until it was confirmed to join the main radial artery (Figs 3 and 4). It appeared to be the dorsal palmar branch of the radial artery.

The tourniquet was then released to ensure the skin paddle was adequately perfused by the superficial palmar branch between the FCR and BR. A vascular clamp was applied to the dorsal palmar branch to confirm that the skin paddle was adequately perfused by the superficial branch alone, which it was. The dorsal branch was then ligated and the radial forearm free flap raised in the traditional way. The flap was inset and anastomosed to the facial artery end-to-end and the venae comitantes anastomosed to the internal jugular vein end-to-side. Adequate flap perfusion and drainage were confirmed. There were no issues with flap perfusion postoperatively and the patient made an uneventful recovery.

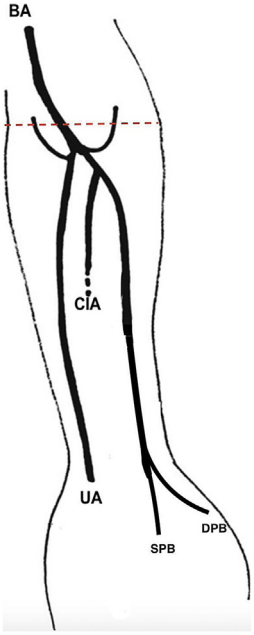

Fig. 3. Diagrammatic representation of normal distal branching of the radial artery. BA, brachial artery; UA, ulnar artery; CIA, common interosseous artery; SPB, superficial palmar branch of the radial artery; DPB, deep palmar branch of the radial artery. The red dotted line indicates the antecubital fossa.

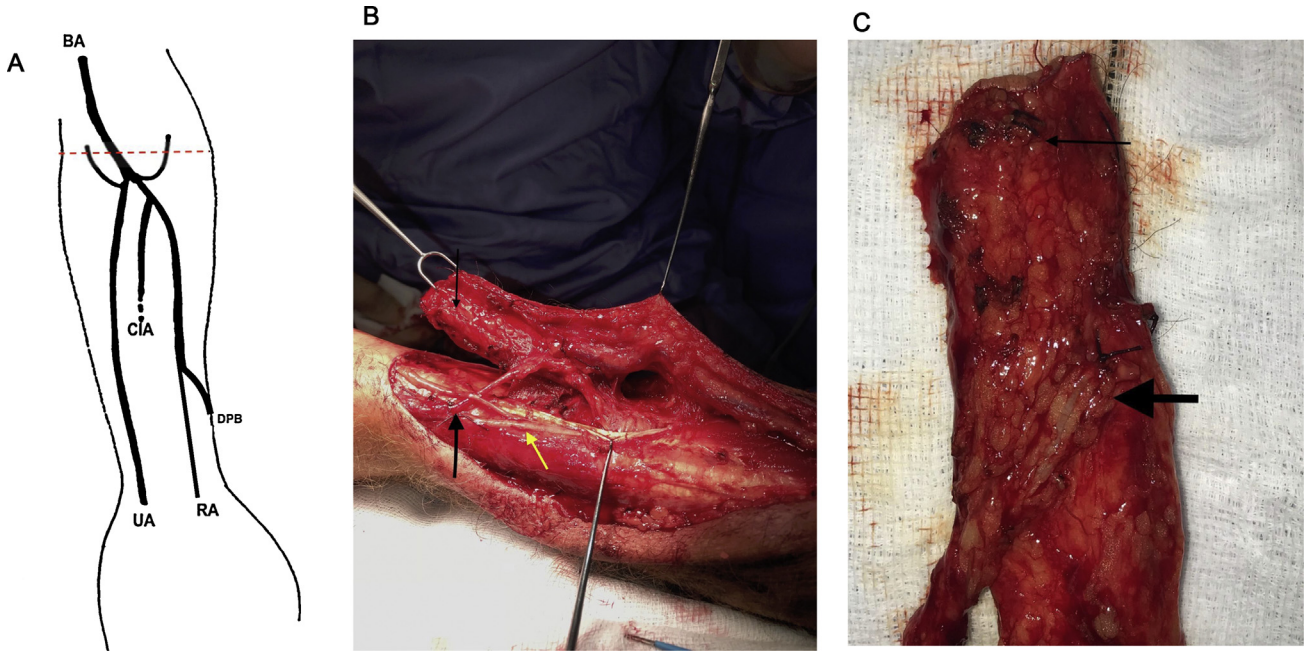

Fig. 4. (A) Diagrammatic representation of the anomalous distal branching of the radial artery (RA) into the deep palmar branch (DPB) approximately 4 cm proximal to the first wrist crease in case 2. BA, brachial artery; UA, ulnar artery; CIA, common interosseous artery. The red dotted line indicates the antecubital fossa. (B) Intraoperative photograph demonstrating the branching of the radial artery while raising the flap. The superficial palmar branch (thin black arrow) was confirmed to be perfusing the overlying skin when the larger dorsal palmar branch (thick black arrow) was clamped. Note also the branching of the superficial radial nerve (yellow arrow) with the thenar branch crossing superficial to the deep palmar branch of the radial artery. (C) Intraoperative photograph demonstrating the branching on the undersurface of the skin paddle.

Discussion

Several radial anomalies have been described in the literature, particularly in relation to radial forearm free flap harvest (Table 1)[3,8–31]. Most variations occur at the proximal anastomosis of the radial artery to the brachial artery, highlighting the importance of following the radial artery to its origin at the brachial artery before ligating any branches. The usual bifurcation of the brachial artery into the radial artery and ulnar artery is seen in only 70% of cases[32]. This bifurcation usually occurs about 1 cm distal to the antecubital fossa. The radial artery then usually runs deep to the brachioradialis muscle proximally, superficial to the pronator teres between the muscle bellies of the brachioradialis and the flexor carpi radialis. Distally, it becomes more superficial, covered by the deep fascia, superficial fascia, and the skin. The variations reported in the reconstructive literature include high origin of the radial artery[8,13,14,21,24,27], superficial dorsal antebrachial artery[8,18,21,25,30], and duplication of the radial artery (most commonly lateral to the dominant radial artery)[15,28,29]. Some have described a similar duplication of the radial artery with the aberrant artery medial to the dominant radial artery[12]. A summary of the reported anomalies is provided in Table 1.

Funk et al. (1995)[21] described one case of a distal take-off of the radial artery deep to the pronator teres muscle where the brachial artery was deep to the pronator teres. In this case, the pronator teres needed to be divided to facilitate identification of the brachial artery. A similar abnormality was described by Small and Millar[16], also requiring division of the pronator teres to gain access to the proximal radial artery. In their report, the radial artery similarly travelled deep to the pronator teres where it joined the brachial artery approximately 8 cm distal to the antecubital fossa, where the brachial artery then divided into the ulnar and interosseous arteries. It appears that there is no previously reported case of a dominant branch of the radial artery (2.5 mm diameter) travelling deep to the pronator teres and joining the interosseous artery, with a residual smaller radial artery (<1 mm diameter) with high origin above the level of the antecubital fossa. Even though the normal position of the radial artery progressing between the bellies of the flexor carpi radialis and brachioradialis could be seen, it was prudent to make sure to be careful when dividing the muscular branches. As the venae comitantes followed the smaller branch of the radial artery, the smaller radial artery was followed up to the antecubital fossa, and the veins were used for venous anastomosis as well as the cephalic vein.

In the second case, the unusual branching of the radial artery also made it difficult to determine the skin paddle design. The normal radial artery branches at the level of the wrist into the superficial palmar branch (which joins the superficial palmar arch) and the deep palmar branch (which joins the deep palmar arch). The deep palmar branch crosses the anatomical snuff box to join the deep palmar arch, and the princeps pollicis branches off from this to supply the thumb. The concern during the dissection was that the skin perforators would be further proximal in the forearm. Hence, once the vascular anatomy was exposed and dissected, the tourniquet was released to ensure adequate perfusion to the skin paddle along the superficial palmar branch alone. Once this was confirmed, the deep palmar branch was ligated and

Table 1. Summary of reported anomalies of the radial artery. (Reproduced and modified with permission from Bhatt et al., 2009[12].)

Authors	Anomaly of radial artery	Brief description
McCormack et al. (1953)[8]	High origin of the radial artery Superficial dorsal antebrachial artery	750 cadaver extremities studied revealed anatomical variations of the radial artery in 4.3% of the sample and 81.3% of all anomalies encountered
Weathersby (1956)[13]	High origin of the radial artery	408 extremities studied revealed departure from normal textbook anatomy in 18.8% of specimens
Coleman and Anson (1961)[14]	High origin of the radial artery Persistent median artery	650 dissected specimens studied
Kadanoff and Balkansky (1966)[15]	Duplication of the radial artery	Case report
Small and Millar (1985)[16]	Radial artery passing deep to the pronator teres	Case report
Poteat (1986)[17]	Absent radial artery	Cadaver dissection single specimen
Uglietta and Kadir (1989)[9]	High origin of the radial artery	100 upper extremity arteriograms reviewed revealed anomalies of the radial artery in 9% of cases
Hedén and Gylbert (1990)[18]	Superficial dorsal antebrachial artery	Case report
Bass (1991)[11]	Hypoplasia of the radial artery	Case report; association with VATER syndrome
Otsuka and Terauchi (1991)[19]	Aberrant dorsal course of the radial artery around Lister's tubercle	Case report
Madaree and McGibbon (1993)[20]	Absence of perforators from the radial artery to the skin	Case report
Funk et al. (1995)[21]	Distal origin of the radial artery deep to the pronator teres Superficial dorsal antebrachial artery High origin of the radial artery	Review of experience with 52 forearm flaps
Lee et al. (1995)[22]	Hypoplasia of the radial artery	Case report; association with Klippel–Feil syndrome
Mordick (1995)[23]	Aberrant mid-axial vessel arising directly from the axillary artery	Case report
Icten et al. (1996)[24]	High origin of the radial artery	Case report
Sasaki et al. (2000)[25]	Superficial dorsal antebrachial artery	Case report
Porter and Mellow (2001)[26]	Absent radial artery	Case report
Rodríguez-Niedenführ et al. (2001)[27]	High origin of the radial artery in 20.3% of the sample Superficial radial artery	192 embalmed cadavers examined; variable terminology unified into a homogeneous classification following an extensive review of the literature and meta-analysis of results
Martín-Granizo et al. (2002)[10]	Superficial radial artery lateral to the normal vessel and originating from it	Case report
Acarturk and Newton (2004)[28]	Accessory branch of the radial artery at the level of the mid forearm extending laterally subcutaneously into the dorsal wrist	Case report
Bumbasirević et al. (2005)[29]	Duplication of the radial artery close to the cephalic vein	Case report
Morris et al. (2005)[30]	Superficial dorsal antebrachial artery	Case report
Acarturk et al. (2008)[3]	Presence of median artery arising from the radial artery Single small proximal perforator supplying the overlying skin Common interosseous artery originating from the radial artery	Case report
Bhatt et al. (2009)[12]	Radial artery divided into medial and lateral branches (accompanied by their respective venae comitantes) about 1.5 cm from the bifurcation of the brachial artery	Case report
Thiagarajan and Dhar (2017)[31]	Branching of the radial artery at the wrist (two cases)	Case reports

the original skin paddle was still used for reconstruction. These anomalies highlight the importance of not dividing any large branches of the artery until the complete vascular anatomy is made clear by completing the dissection first.

Should duplex ultrasound be performed before harvesting radial forearm free flaps due to the occurrence of vascular anomalies? In a study by Ganesan et al. (2010)[33], the Allen's test and colour flow duplex ultrasonography were performed prior to

surgery for 121 patients listed for a radial forearm free flap reconstruction. Among these patients, five had an alternative flap selected as a consequence of the duplex assessment. However, four of these five patients also had an abnormal Allen 's test on examination. In the one case with a normal Allen's test result, the decision not to proceed with a radial forearm free flap harvest was the duplex ultrasonography showing a spindly ulnar artery with considerable tapering off of the artery at the wrist[33]. In another study, an abnormal Allen's test was found to be associated with significant atherosclerotic disease along the whole course of the radial artery, leading to the flap being discarded[34].

These studies and others highlight the importance of considering a colour duplex ultrasound prior to radial forearm harvest in the presence of an abnormal Allen's test[7]. Overall, the Allen's test demonstrates a sensitivity of 100% and a specificity of 75%, so the authors' team consider a duplex ultrasound only in patients with an abnormal Allen's test, which is consistent with other studies[7]. In the cases presented in this paper, it would have potentially been valuable to perform a duplex ultrasound for the second case when the aberrant branching of the radial artery was noted during the Allen's test. In conclusion, surgeons performing microvascular reconstructions need to be aware of the common anatomical variations of the radial artery. During dissection, it is important to not divide any large branches until adequate exposure of the arterial system is performed. Where anomalies are present, early identification may allow the surgeon to then modify his harvest with successful anastomosis and flap perfusion.

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Competing interests

There are no conflicts of interest to declare.

Ethical approval

No ethical approval was needed. Signed patient consent was all that was required by the hospital.

Patient consent

Written consent was obtained from the patients to include the photographs in a publication.

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