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Anatomical Basis of the Occipital Artery-Posterior Inferior Cerebellar Artery Bypass (OA-PICA Bypass)

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ABSTRACT: Revascularization allows the restoration of blood flow to a brain territory deprived of it, and a solid knowledge of cerebral vascular anatomy forms the foundation for mastering this practice. The aim of this study was to describe the main anatomical elements involved in the occipital artery-posterior inferior cerebellar artery technique and to briefly present the anastomosis procedure in cadaveric preparations. Four heads with cerebellums fixed in 5 % formalin were used. The dissections were carried out with left-hand forceps, scissors, 9-0 sutures, a high-resolution photographic camera, micro dissection instruments, latex, and resin. The dissection of the occipital artery and the posterior inferior cerebellar artery (PICA) corresponded to classical anatomical and neurosurgical descriptions. Each segment of the PICA and its relationships with posterior fossa neural structures were exposed. The bypass performed in cadaveric preparations highlighted the importance of acquiring this skill through laboratory training before clinical application. The dissections allowed visualization of the vertebral artery with its segments V1–V4; the PICA with its five segments, anterior medullary, lateral medullary, amygdalo-medullary, telo-velo-tonsillar, and cortical; and the occipital artery with its three segments, oblique ascending, transverse, and vertical ascending. Both in the initial approach and during intraoperative microsurgical dissection, preserving the integrity of these vessels requires significant technical expertise, which can only be achieved through repeated laboratory practice. In summary, vascular neuroanatomy revealed the detailed segmentation of the occipital and PICA arteries, confirming their anatomical relationships with neural structures such as the pons, medulla, fourth ventricle, and cerebellum. The bypass practice in cadaveric specimens demonstrated that it is possible to successfully develop the technique under the microscope, reinforcing the necessity of laboratory training before performing it in the operating room with patients.

KEY WORDS: Microsurgical anatomy; OA-PICA by-pass; Occipital artery; Posterior inferior cerebellar artery; Cadaveric dissection.

INTRODUCTION

Cerebral revascularization is a complex procedure used in modern neurosurgery and has gained significant ground within the field. It allows the restoration of blood flow to a territory lacking it due to various congenital or acquired pathologies (Campero & Ajler, 2019). The magnitude and complexity of the procedure, along with the extensive learning curve, result in few specialists being truly prepared to master this technique and perform it successfully in their patients. Extensive and continuous microsurgical practice is essential for acquiring the necessary procedural skills, and thorough knowledge of cerebral vascular anatomy is the fundamental foundation required to begin mastering this practice (Rubino *et al*., 2021).

The aim of the present work is to provide a description of the main anatomical elements related to the cerebral revascularization technique of the Occipital-to-Posterior Inferior Cerebellar Artery bypass (OA–PICA bypass) and to briefly present the anastomosis technique in cadaveric specimens.

MATERIAL AND METHOD

Four heads (8 sides) and three cerebella fixed in 5 % formalin were used.

The dissections were performed using standard dissection instruments (left-hand dissecting forceps with and without rat-tooth tips; Metzenbaum, Iris, and Mayo scissors), acrylic material, and 9-0 and 10-0 sutures. High-resolution cameras, microsurgical instruments (forceps, needle holders, scissors), and vessel injection with latex and resin were also used.

RESULTS AND DISCUSSION

Cerebral revascularization is an extremely complex procedure that allows the restoration of adequate blood supply to regions of the parenchyma suffering from acute or chronic lack of blood flow. Cerebral bypass is one such procedure and consists of creating an anastomosis between two vessels that are not normally interconnected, so that the flow from one can be redirected to nourish the cerebral territory of the other. In many cases, the interposition of an external graft is required to comfortably bridge the distance between the two vessels. To successfully perform a cerebral bypass, it is essential to have detailed knowledge of the vascular and cisternal anatomy of the cranial cavity, as well as of extracranial vessels that may serve as flow donors, such as the superficial temporal, occipital, and radial arteries, and the saphenous veins (Rhoton, 2021).

In the posterior fossa, the cerebellum and brainstem receive their blood supply from the vertebrobasilar system, whose two main trunks are the vertebral arteries and the basilar artery. One of the branches belonging to the lower neurovascular complex is the Posterior Inferior Cerebellar Artery (PICA), which is vitally important for the irrigation of the brainstem and inferior cerebellum.

In the dissections performed in the present study, we were able to observe anatomical relationships in two key areas. First: those of the occipital artery. The dissections confirmed the anatomy described in classical anatomical texts (Testut & Latarjet, 1954), including the tortuosity of the artery, its rich anastomotic network with the other scalp vessels, and its anastomosis with the contralateral homonymous artery, features that, from an anatomical standpoint, allow us to select it as a donor vessel for practicing and performing the anastomosis. Second: the dissection of the posterior fossa and the course of the Posterior Inferior Cerebellar Artery. We were able to visualize the segments described in neurosurgical anatomy texts and their important relationships with the pons, medulla, roof of the fourth ventricle, and inferior cerebellum, knowledge that is crucial for performing an approach that ensures safe access without injury.

Finally, the dissection and exposure of the anatomical structures allowed us to carry out the end-to-side Occipital Artery–Posterior Inferior Cerebellar Artery anastomosis, adhering to the key steps described in the surgical procedure and working under microscopic visualization. The considerable difficulty of performing this anastomosis in such a restricted space, using magnification and microsurgical tools, highlights the importance of prior laboratory practice in anatomical training environments (Yuan *et al*., 2023).

Vertebral Artery:

The vertebral artery (VA) is the ascending collateral branch of the subclavian artery. It supplies the upper portion of the spinal cord, the brainstem, and the cerebellum. Its course is divided into four segments:

1. First segment (V1): It begins at the pre-scalenic segment of the subclavian artery, always ascending and forming part of the superior boundary of the supra-retropleural recess [of Sébileau], passing superior to the stellate ganglion on the posterior surface of the pulmonary apex. It ends at the vertebral artery triangle [of Waldeyer], just before entering the transverse foramen of the sixth cervical vertebra.

2. Second segment (V2) or intraforaminal segment: It begins in the transverse foramen of the sixth cervical vertebra. The artery ascends vertically through the successive transverse foramina of the cervical vertebrae until it crosses the transverse foramen of the atlas, where this segment ends. It is accompanied by the vertebral vein and the vertebral nerve [of François-Franck].

3. Third segment (V3) or suboccipital segment: It begins as the artery exits the transverse foramen of the atlas, forming a horizontal curve with medial concavity posterior to the lateral masses of the atlas. At this point, the artery can be visualized within the suboccipital triangle [of Tillaux], accompanied by the suboccipital venous plexus [of Zolani] and the suboccipital nerve. This segment ends when the artery traverses the posterior atlanto-occipital membrane and the dura mater. (Fig. 1.).

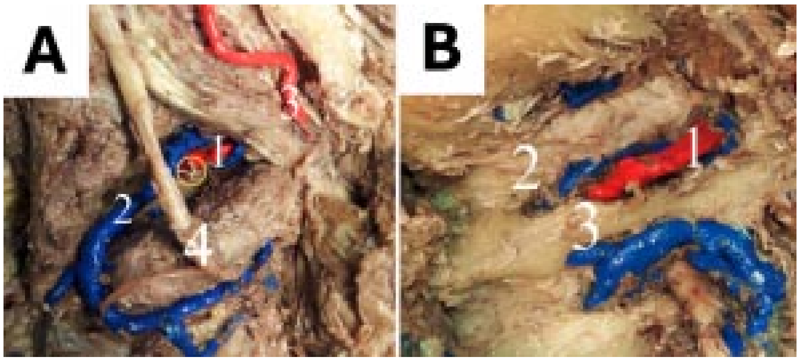

Fig. 1.1. A) The Suboccipital Triangle is visualized with its boundaries and contents, among them, and most importantly, the V3 segment of the Vertebral Artery, surrounded by the suboccipital venous plexus, injected with colored resin. 1: Vertebral artery; 2: Suboccipital venous plexus; 3: Occipital artery; 4: Greater occipital nerve; Yellow circle: Suboccipital nerve. B) Once the boundaries of the Triangle are removed, the entire V3 segment of the Vertebral Artery can be seen coursing in the groove on the superior surface of the posterior arch of the atlas, and the moment when the artery perforates the posterior atlanto-occipital membrane. 1: Vertebral artery; 2: Posterior atlanto-occipital membrane; 3: Posterior arch of the first cervical vertebra.

4. Fourth segment (V4) or intradural segment: It begins upon crossing the cervical dura mater, ascending along the anterolateral region of the medulla oblongata and ending at the pontomedullary junction, where it anastomoses with the contralateral VA to form the basilar artery. Branches arising from this segment include the posterior meningeal artery, the anterior and posterior spinal arteries, and the posterior inferior cerebellar artery (PICA).

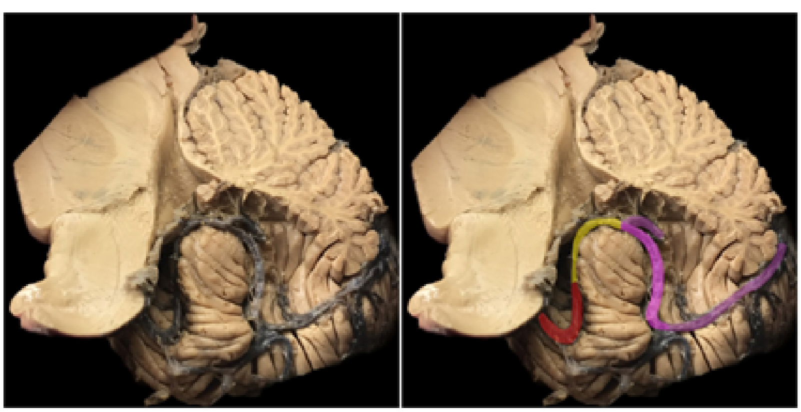

Fig. 2. From a medial view of the brainstem and cerebellum in a sagittal section, the left image shows the course of the right PICA giving off its terminal branches, and the right image highlights the visible segments in color: red (tonsillomedullary segment), yellow (telovelotonsillar segment), and violet (cortical segment).

Posterior Inferior Cerebellar Artery (PICA):

The posterior inferior cerebellar artery (PICA) is responsible for supplying the posteroinferior portion of the cerebellum (Nisson *et al*., 2019, 2020). It arises from the vertebral artery in most cases, although it may originate from the basilar artery, either with a single trunk or in common with the contralateral PICA or with the anterior inferior cerebellar artery (AICA). Five segments are described along the course of the PICA (Rhoton, 2021):

1. Anterior medullary segment: This segment begins at the origin of the artery and ends at the most prominent portion of the inferior olive. If the PICA originates laterally to the spinal cord, this segment may be absent. The most important relationship in this segment is with the rootlets of the apparent origin of the hypoglossal nerve, where the artery courses with three possible patterns of variability relative to them: cranial, caudal, or between the rootlets. The PICA gives off perforating branches to the spinal cord at this segment and the next one.

2. Lateral medullary segment: It begins at the most prominent point of the inferior olive and ends at the level of the rootlets of the vagus and accessory nerves. In this segment, the PICA is considered, together with the lower cranial nerves, part of the neurovascular pedicle of the cerebellopontine angle.

3. Tonsillomedullary segment: This segment begins at the level of the lower cranial nerve rootlets and ends at the caudal half of the cerebellar tonsil. As it passes by the tonsil, the artery forms a caudal or infratonsillar loop, which may be absent when the artery courses medial to the tonsil. In this segment and the next, choroidal branches emerge to form the choroid plexus of the fourth ventricle along with branches from the anterior inferior cerebellar artery. (Figs. 1).

4. **Telovelotonsillar segment:** It begins when the artery leaves the caudal half of the tonsil and courses medially to it, ending when it exits the fissure formed between the vermis, the tonsil, and the cerebellar hemisphere (the cerebellomedullary fissure). In this segment, a cranial loop is formed, located caudal to the fastigial nucleus. (Fig. 2).

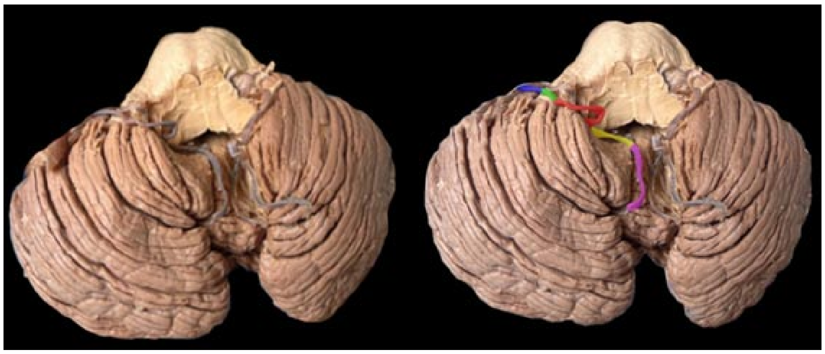

Fig. 3. Inferior view of the brainstem and cerebellum after removal of the medulla oblongata. The left image shows the course of both posterior inferior cerebellar arteries; the right image shows their segments highlighted in color: blue (anterior medullary segment), green (lateral medullary segment), red (tonsillomedullary segment), yellow (telovelotonsillar segment), and violet (cortical segment).

5. Cortical segment: This segment begins in the fissure formed between the vermis, tonsil, and cerebellar hemisphere. In this segment, the suboccipital cortical branches emerge. At the level of segments 3 and 4 (with the most frequent bifurcation site being the telovelotonsillar fissure), the PICA divides into two trunks: medial and lateral. The medial trunk supplies the inferior vermis and the adjacent parts of the tonsil and cerebellar hemisphere, while the lateral trunk supplies the corresponding suboccipital cerebellar hemisphere and gives off small branches to the tonsil. (Figs. 3 & 4)

Fig. 4. Left image: ventral view of the brainstem and cerebellum with the vertebrobasilar system in situ. Right image: isolated vertebrobasilar system.

Occipital artery (OA)

As a collateral branch of the external carotid artery, it supplies the occipital region of the scalp. Its course is divided into three segments (Testut & Latarjet, 1954):

1. Oblique ascending segment: It begins at the origin of the OA on the posterior surface of the external carotid artery and courses inferiorly and deeply to the posterior belly of the digastric muscle, crossing the hypoglossal nerve. It ends at the medial side of the mastoid process.

2. Transverse segment: It begins on the medial surface of the mastoid process and courses deep to the splenius, sternocleidomastoid, and posterior belly of the digastric muscle. It finally situates itself between the semispinalis capitis and the inferior oblique muscles, ending deep to the trapezius muscle. Collateral branches arise here: the superior sternocleidomastoid artery, the stylomastoid artery, and the meningeal artery.

3. Vertical ascending segment: It begins deep to the trapezius muscle and ends after perforating it in the occipital region. In this segment, the tortuosity of the OA becomes more pronounced, and its terminal branches emerge: a lateral branch directed toward the posterior auricular muscle to anastomose with the posterior auricular artery, and a medial branch that ascends vertically along the midline to anastomose with the contralateral medial branch and with the posterior branches of the superficial temporal artery. (Fig. 5)

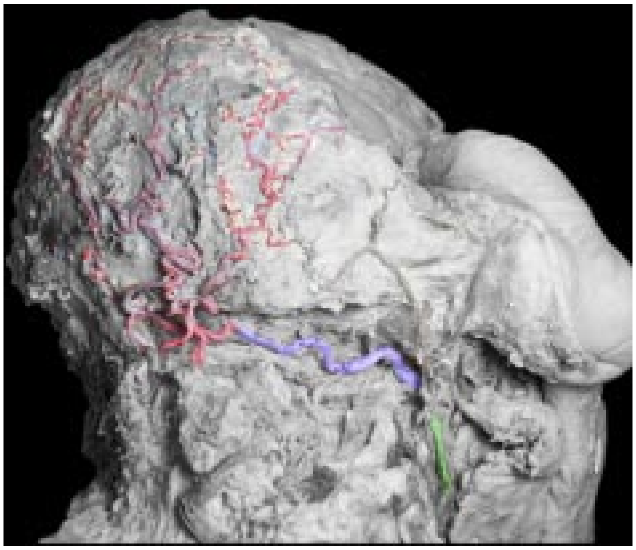

Fig. 5. Posterior view of the occipital region showing the full course of the occipital artery and its scalp branches. The three arterial segments are shown in color: green (oblique ascending segment), violet (transverse segment), red (vertical ascending segment).

Surgical Neuroanatomy

Aneurysms of the PICA and the vertebrobasilar junction are the second most frequent in the posterior circulation, and the surgical approaches to both are similar (Matsushima *et al*., 2018; Cavagnaro, 2022). The access route for clipping, as well as for performing the bypass in general, uses the far-lateral or lateral suboccipital approach, which provide broad exposure of the lateral aspect of the brainstem and the inferior and lateral surfaces of the cerebellum (Lawton, 2018; Hendricks & Spetzler, 2019).

Procedure performed on the cadaveric specimen: A reversed J-shaped incision is made, with the longer limb toward the midline, removing the subcutaneous and muscular layers in a single block in the cadaveric specimen (Fig. 6).

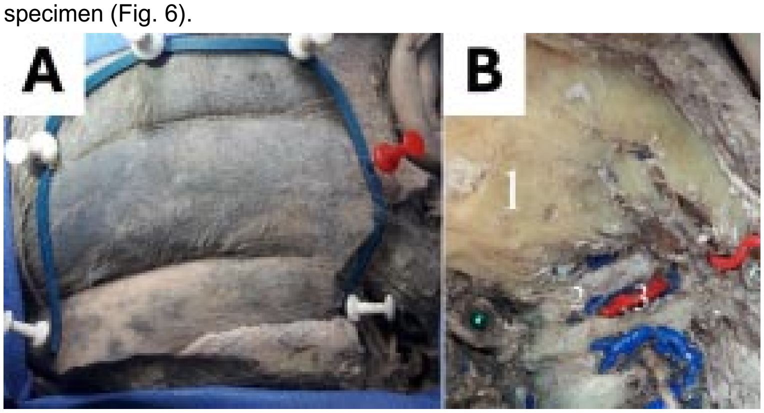

Fig. 6. A: Right occipital ncisi with the ncisión line marked in blue. B: Bone exposure after removing soft tissues. 1: Occipital bone squama; 2: Posterior atlanto-occipital membrane; 3: Vertebral artery.

The occipital artery is dissected and isolated, preserving it as the donor vessel, and then a wide craniotomy is performed, which may include removal of the posterior arch of the atlas, followed by a dural opening (durotomy), taking care to preserve the transverse and sigmoid venous sinuses (Fig. 7).

This provides a lateral view of the cerebellum and brainstem, allowing identification of the Posterior Inferior Cerebellar Artery, its visible segments, and its nearby anatomical relationships (Fig. 8).

The free end of the donor vessel (Occipital Artery) is prepared by creating a fish-mouth opening to increase its diameter (Fig. 9).

The ends of the recipient vessel are clamped at the selected segment, and a longitudinal incision is made. The two openings are approximated to perform the anastomosis under microscopic magnification using microsurgical sutures. The first stitch is placed at the heel of the donor vessel, the second at its apex, the third along the non-visible wall, and the fourth along the visible wall, the latter using simple interrupted non-absorbable 9-0 or 10-0 sutures (Fig. 10).

Once the anastomosis is completed, patency is checked by injecting dye into the artery and observing its passage.

CONCLUSION

Both classical vascular neuroanatomy and contemporary neurosurgical anatomy were clearly demonstrated in the dissections, allowing visualization of each of the segments of the Occipital Artery and PICA. The anatomical relationships of the PICA with important neural structures, such as the pons, medulla, fourth ventricle, and cerebellum, were also confirmed. Regarding the bypass practice on the cadaveric specimen, the technique was successfully performed under the microscope, highlighting the necessity of prior laboratory practice before carrying it out in the operating room with patients.

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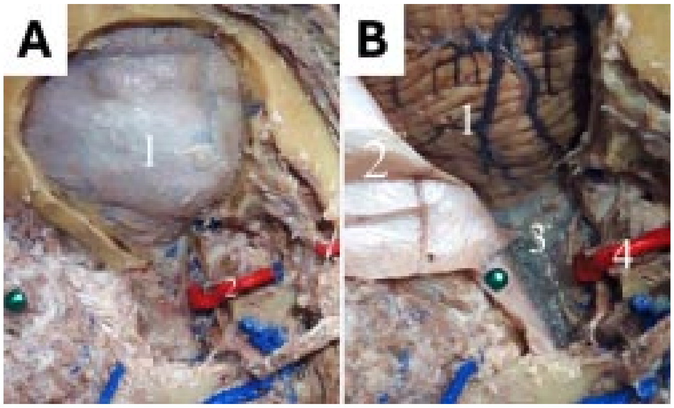

Fig. 7. A: After the craniotomy, the dura mater covering the posterior fossa and upper cervical region is observed. The posterior arch of the atlas has also been removed, leaving the vertebral artery freely mobile. 1: Dura mater; 2: Vertebral artery. B: The durotomy (incision and reflection of the dura) allows exposure of the cerebellar hemisphere and the posterior arachnoid of the upper cervical region. 1: Cerebellar hemisphere; 2: Dura mater; 3: Arachnoid; 4: Vertebral artery.

Fig. 10. Left: nesting site of one end of the anastomosis under microscopic visualization. Right: anastomosis between the occipital artery and the posterior inferior cerebellar artery, highlighted with a red circle.

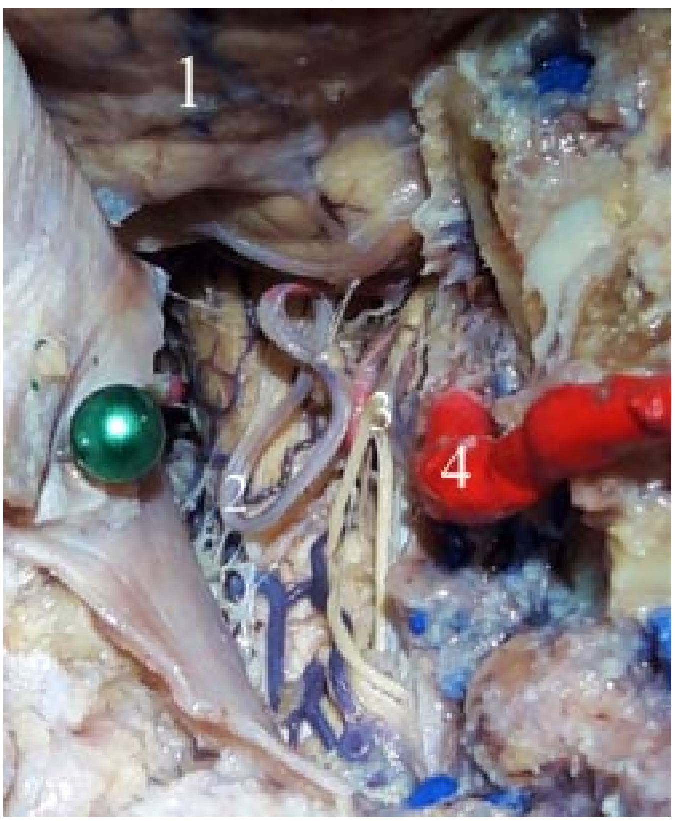

Fig. 8. Dorsal view of the spinal cord and medulla oblongata. 1: Cerebellar hemisphere; 2: Caudal loop of the posterior inferior cerebellar artery; 3: Accessory nerve; 4: Vertebral artery.

Third Chair of Anatomy of the same Faculty, and the members of the Neuroanatomy Laboratory.

Conflicts of Interest: The authors of this work declare no conflicts of interest.

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Roles in the Study: Axel Colombo: Writing and information collection, Valentina Duzer: Information collection, Valeria Trofa: Information collection, Daiana Gonzalez: Methodology

Fabian Dodaro: Resources and supervision.

Ethical Considerations: The cadaveric material used in this study was obtained through the voluntary body donation program of the Faculty of Medicine, University of Buenos Aires, Argentina. This program is approved and supervised by the institution's Bioethics Department.

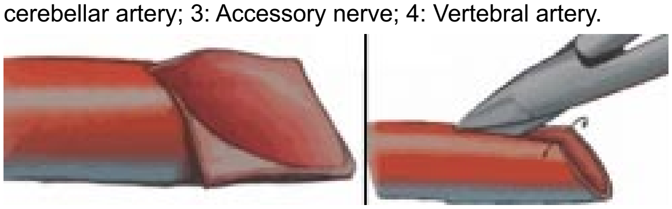

Fig. 9. A diagram of the "fish-mouth" opening of the donor vessel (left image) and how it is performed (right image).

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