MIDDLE CEREBRAL ARTERY REVASCULARIZATION

ANATOMICAL STUDIES AND CONSIDERATIONS ON THE ANASTOMOSIS SITE

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ABSTRACT - In the surgical management of skull base lesions and vascular diseases such as giant aneurysms, involvement of the internal carotid artery may require the resection or the occlusion of the vessel. The anastomosis of the external carotid artery and the middle cerebral artery with venous graft may be indicated to re-establish the blood flow. To determine the best suture site in the middle cerebral artery, an anatomical study was carried out. Fourteen cerebral hemispheres were analysed after the injection of red latex into the internal carotid artery. The superior and inferior trunk of the main division of the middle cerebral artery have more than 2 mm of diameter. They are superficial allowing an anastomosis using a venous graft. The superior trunk has a disadvantage, it gives rise to branches for the precentral and post-central giri. The anastomosis with the inferior trunk presents lower risk of neurological deficit even though the angular artery originates from it.

KEY WORDS: middle cerebral artery, anastomosis, revascularization, anatomy.

Revascularização da artéria cerebral média: estudo anatômico e considerações sobre o local de sutura

RESUMO - No tratamento cirúrgico das lesões da base do crânio e patologias vasculares como aneurismas gigantes, a ressecção ou oclusão da artéria carótida interna pode ser necessária. A anastomose das artérias carótida externa e cerebral média com interposição de enxerto venoso pode ser utilizada para restabelecer o fluxo sanguíneo. Para determinar o melhor local de sutura na artéria cerebral média, realizou-se um estudo anatômico. Quatorze hemisférios cerebrais foram analisados depois da injeção de látex vermelho na artéria carótida interna. Os ramos superior e inferior da divisão principal da artéria cerebral média têm mais de 2 mm de diâmetro. Eles são superficiais e permitem uma anastomose utilizando um enxerto venoso. O tronco superior tem a desvantagem de dar origem aos ramos para os giros pré e pós-centrais. A anastomose com o tronco inferior apresenta menor risco de déficit neurológico, apesar da artéria angular ter origem desse vaso.

PALAVRAS-CHAVES: Artéria cerebral média, anastomose, revascularização, anatomia.

After acute occlusion of the middle cerebral artery (MCA) by thrombus or embolus, 18 to 80% of the patients develop infarct with neurological deficits[1,9,11,16,35]. The arterial blood reflow can prevent serious neurological deficits in many of these patients[10,17,31,34]. Several options for the MCA revascularization have been used: embolectomy[16,34], direct arterial graft[7,18], vein graft[21], superficial temporal artery to MCA anastomosis and carotid artery (internal or external) to MCA anastomosis using saphenous vein graft[4,12,20,24,25,27-30].

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In the surgical management of the cavernous sinus diseases[15], the internal carotid artery (ICA) can be involved or even infiltrated by the lesion. It may be necessary to sacrifice the vessel for radical tumour removal and revascularization of the ICA may be indicated. The anastomosis of the petrous or cervical portion of ICA with the supraclinoid portion, using a vein graft, has been performed in skull base surgery[23]. In a recent lecture at our Service[22], Sekhar presented the advantages of the anastomosis of the external carotid artery to the MCA for cerebral revascularization over the anastomosis with the petrous ICA, in cavernous sinus surgery. To determine the best suture site in the MCA, an anatomical study of the calibre and position of the arterial branches of the MCA was carried out.

MATERIAL AND METHODS

The internal carotid arteries of fourteen human cerebral hemispheres of adult cadavers, fixed with 50% formaldehyde solution, were injected with approximately 70 ml red latex (Neoprene, DuPont). The anterior portion of the temporal lobe was removed for better visualization of the MCA, in order to study and classify the MCA branches. The perforating arteries from the proximal MCA (M1) were observed and classified by their location and types of division. The cortical branches were classified according to their courses and territory of blood supply. Diameters of the MCA, characteristics of the origin of the MCA and the trunk after the main bifurcation, and the presence of anomalous arteries were studied. The distances from the MCA origin to the main bifurcation (M1 segment), and from the main bifurcation to the first trunk division (M2 segment) were measured.

RESULTS AND LITERATURE REVIEW

The calibre at the origin of the MCA (11 hemispheres, 78.57%) varied from 2.9 to 3.9 mm (mean 3.2 mm). According to the literature the MCA calibre varies from 2.0 to 4.9 mm, averaging 3.0 mm[3,6,8,33].

The MCA most frequent pattern of the main division was bifurcation (85.57%). It was observed in 12 hemispheres (Figs 1 and 2). Trifurcation (7.15%) and a single trunk (7.15%) were found in one specimen each. According to different authors the frequency, of bifurcation ranges from 64% to 95%, trifurcation from 5% to 29% and single trunk from 4% to 6%[2,3,6,19,32,33].

The bifurcation pattern was: (a) superior trunk giving origin to the orbitofrontal, prefrontal, precentral, central and anterior parietal arteries; (b) inferior trunk to the posterior parietal, anterior temporal, middle temporal, posterior temporal, temporo-occipital, angular and temporopolar arteries. According to Umanski et al.[33] the posterior parietal artery originates from the superior trunk, beyond the other branches related and the inferior trunk originates only the temporal, anterior, middle and posterior arteries.

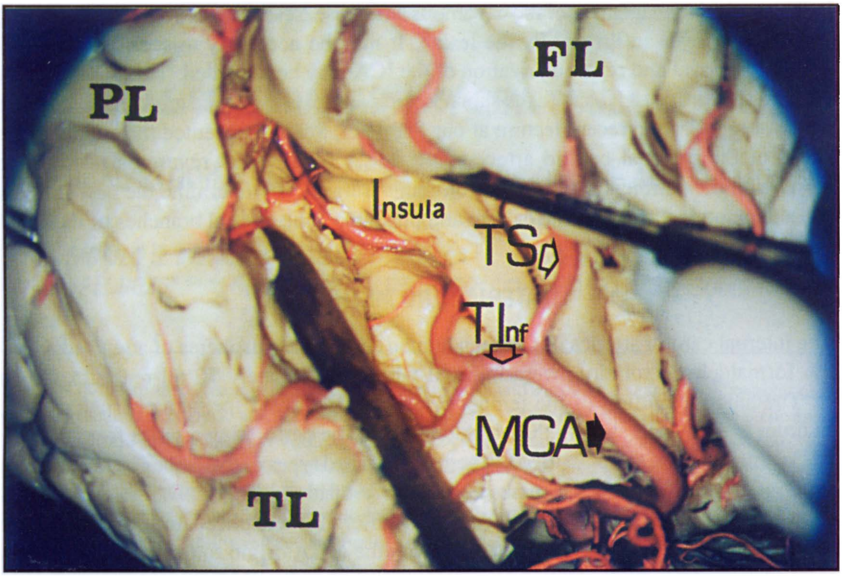

Fig 3. The middle cerebral artery (MCA) gives rise to the superior (TS) and the inferior trunks (T Inf). Their branches are originated at the insula. The frontal (FT), parietal (PL) and temporal lobes (TL) are also seen.

The trifurcation pattern was: (a) the orbitofrontal, prefrontal, precentral and central arteries from the superior trunk; (b) the anterior parietal, posterior parietal, temporo-occipital and angular arteries from the middle trunk and; (c) the anterior temporal, middle temporal and posterior temporal arteries from the inferior trunk. The same was found in the literature, except for the presence of prefrontal and temporo-occipital arteries[33].

In the case of MCA as undivided trunk the anterior temporal artery originated from an independent branch. The orbitofrontal and prefrontal arteries originated from the same branch as well as the precentral and central arteries. The other branches were absent.

From 11 hemispheres, which presented bifurcation pattern of the MCA, 6 showed a dominant superior trunk (54.5%) and the diameters varied from 2.0 mm to 2.7 mm, averaging 2.29 mm ± 0.26 SD. The other five showed dominant inferior trunk (45.4%), and the diameters varied from 2.3 mm to 3.0 mm, averaging 2.11 mm ± 0.50 SD (Fig 3). No case of non dominant bifurcation was observed. Gibo et al.[6] related non dominant bifurcation in 18%, dominant superior trunk in 28% and dominant inferior trunk in 32% of the hemispheres.

The distance from the bifurcation of the internal carotid artery to the main division of the MCA ranged from 11.45 mm to 26.9 mm, averaging 18.5 mm (Fig 4). According to the literature this distance ranges from 4.3 mm to 19.5 mm[6].

The distance from the main division of the MCA to the first division of the superior trunk studied in 12 hemispheres (85.7%) varied from 5.9 to 18.9 mm (mean 11.9 mm). The distance from the main division of the MCA and the first division of the middle trunk, observed in one hemisphere (7.14%) was 13.9 mm. The distance from the main division of the MCA to the first division of the inferior trunk in 9 cases (64.3%) varied from 8.7 mm to 54.8 mm, averaging 20.4 mm.

Earlier branches of the MCA trunk were observed in 10 hemispheres (71.4%). These arteries supplied the temporal lobe (70%), frontal lobe (20%) and frontal and temporal lobe (10%). The

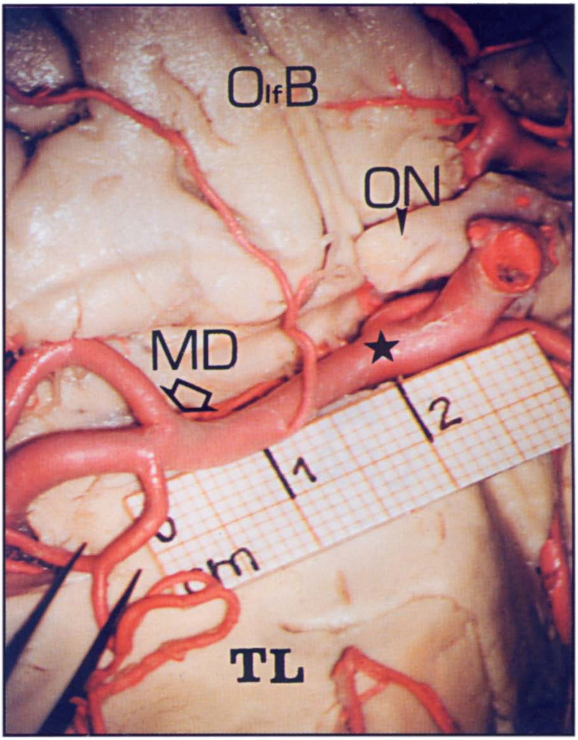

Fig 4. The M 1 segment of the middle cerebral artery is seen from the carotid bifurcation (*) to its main division (MD). The olfactory bulb (Olf B), the optic nerve (ON) and the temporal lobe (TL) are also visualized.

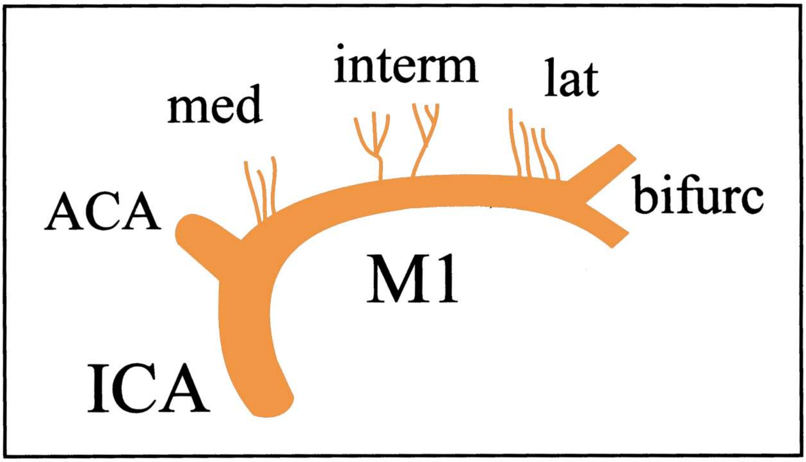

Fig 5. The position of the lateral (lat), intermedial (interm), and medial (med) perforating arteries are showed arising from the M 1 segment of the middle cerebral artery. The internal carotid artery (ICA), the anterior cerebral artery (ACA) and the bifurcation (bifurc) of the middle cerebral artery are indicated.

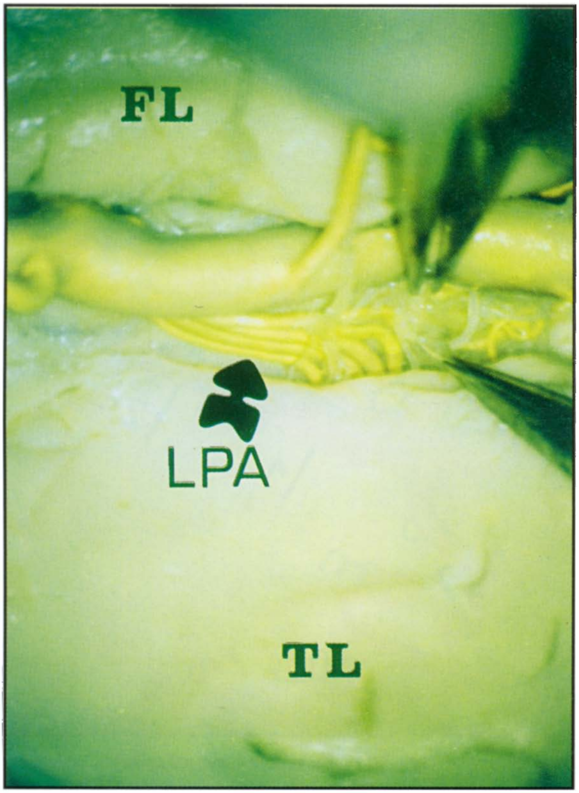

Fig 6. The lateral perforating arteries (LPA) arise from the distal segment of the middle cerebral artery, between the frontal (FL) and temporal lobes (TL).

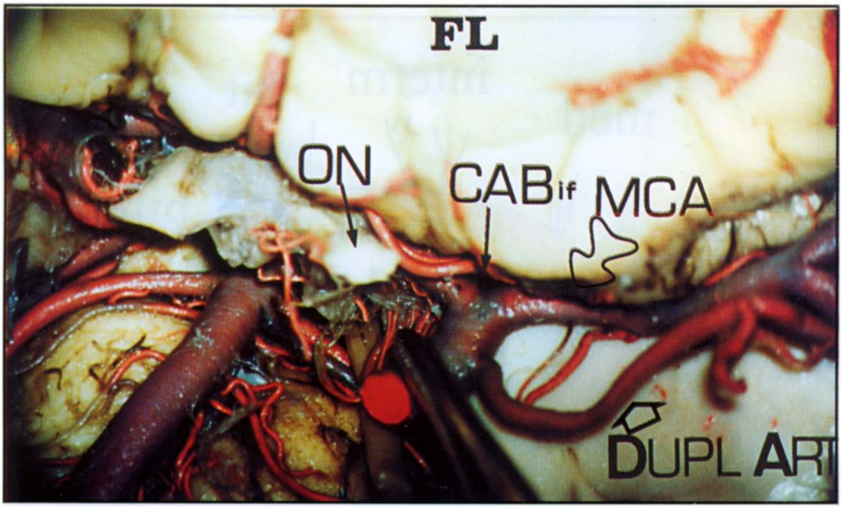

Fig 7. The duplicated middle cerebral artery (Dupl Art) arises from the internal carotid artery. The optic nerve (ON), the carotid artery bifurcation (CABif), the middle cerebral artery (MCA) and the frontal lobe (FL) are also seen.

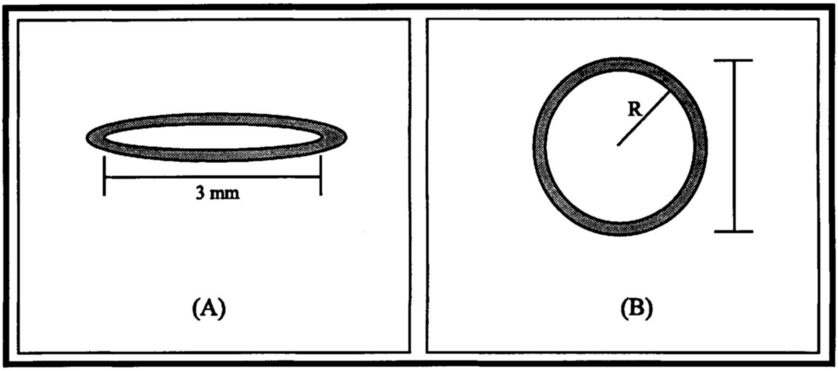

Fig 8. When the artery is clamped, its perimeter corresponds to 2 x 3 mm (A). When it is not clamped, the perimeter corresponds to 2πR (B).

number of earlier branches of the MCA varied from 2 to 5. The most frequent earlier branch was the temporopolar artery, in 80% of the hemispheres, followed by the anterior temporal (40%), orbitofrontal (30%), middle and posterior temporal (20%). According to the literature the incidence of earlier ramification occurs from 61% to 91,9% of the cases. These branches run to the temporal lobe (approximately 77%) and to the frontal lobe (23%)[3,8,33]. The number of earlier branches per hemisphere ranges from 2 to 6, and the temporopolar and anterior temporal arteries are the most frequent[3,8,33].

The perforating arteries varied from 1 to 20 per hemisphere, averaging 11.6. These values are similar to those observed by Rosner et al.[19]. Based on the literature, the perforating arteries of the M1 segment of the MCA were divided in three different groups, considering its origin, composition and morphology (Fig 5). a) The perforating arteries from the medial group arise from the proximal M1 segment, close to the internal carotid artery bifurcation[14]. They were observed in 72,7% of the cases and varied from 2 to 8, averaging 4.4 arteries per hemisphere. They are the least frequent, and are observed, according to the literature, in 50% of the cases, varying up to 8 arteries per hemisphere. b) The perforating arteries from the intermedial group arise from the middle of the M1 segment. The characteristic of this group is the presence of one or two larger arteries forming branch complexes[13,19]. They were observed in all the specimens, and varied from 1 to 11, averaging 3 arteries per hemisphere. Marinkovic et al.[13] observed intermedial perforating arteries in 88% of the hemispheres, and they varied from 1 to 7 arteries, averaging 3 per hemisphere. c) The lateral perforating arteries arise from the distal M1 segment close to its main division (Fig 6). These arteries are S shaped[13,19]. As in the literature, the lateral perforating arteries were considered the most frequent ones. They varied from 1 to 8, averaging 4.8 arteries per hemisphere.

One duplication of the MCA was observed in one hemisphere (7.14%). The diameter of the duplicated artery was 1.4 mm, and it arose from the internal carotid artery (Fig 7). Its origin was situated 4.3 mm from the MCA, and gave rise to the temporopolar, anterior temporal and a lateral perforating artery. Umanski et al.[32] observed the duplicated artery in 1% of the cases. Its diameter was 3.5 mm and it gave rise to the temporal lobe cortical branches and perforating branches.

One accessory MCA was observed in one cerebral hemisphere (7.14%). The diameter of the accessory artery was 1.5 mm. It arose from the anterior cerebral artery and gave rise to the orbitofrontal and Heubner artery. Umanski et al.[32] observed the accessory artery in 2% of the cases. The cortical ramification to the orbitofrontal, precentral and central areas arose from the accessory artery. It also gave rise to the perforating and Heubner arteries.

DISCUSSION

The surgical management of pathologies, such as giant aneurysms or skull base tumours, may carry high risks of lesioning the internal carotid artery (ICA). The cavernous sinus tumours, particularly, may involve or infiltrate the ICA. An ICA to MCA anastomosis may be necessary to preserve the cerebral hemisphere vascularization in order to achieve total tumour removal, with resection of the infiltrated vessel.

Conley[5], in 1953, described 11 cases of ICA anastomosis, using vein grafts, in patients with head and neck tumours. Patients with such lesions, that infiltrate the ICA were previously submitted to a ligature or surgical removal of the ICA, with very high mortality and morbidity.

After this initial experience, other centres performed anastomosis using vein grafts for cerebral revascularization. The anastomosis of the petrous ICA to the supraclinoid portions[26], or the anastomosis of the cervical ICA to the supraclinoid portion[30], using vein graft, have been performed, but it is necessary to clamp the ICA for a long period carrying the risk of ischemia. The anastomosis between the external carotid artery and a calibrous branch of the MCA, using a vein graft, do not require temporally closure of the ICA and reduces the risk of ischemia.

Direct anastomosis, such as the superficial temporal artery (STA) to the MCA branches, may not provide enough blood flow to supply the whole MCA territory. The vein graft allows direct anastomosis from a more calibrous vessel, as the external carotid artery.

The saphena magna is regularly used for the graft. Some centres use one of the branches of the external carotid artery as donor vessel[12]. We have the experience of using the superficial temporal artery[18]. The proximal suture is performed end to end at the bifurcation of the carotid artery. The graft is passed subcutaneously in the preauricular region, and an end to side anastomosis is performed distally. According to Sekhar[22] the artery should have when clamped at least 3 mm of width (Fig 8) in order to provide the adequate blood flow. The perimeter of a circumference is determined by the formula $P=2\pi R$, where P is the perimeter and R is the radius. As the perimeter corresponds to 2 times 3mm, and equalling terms, we have $2x3=2\pi R$ and $R=3/3,1416=0.955$. Therefore, the vessel should have at least a diameter of 1.91 mm. From this anatomical study, it was observed that the branches of the main division of the MCA have more than 2 mm of diameter. The main division of the MCA is situated between 11.45 and 26.9 mm from the bifurcation of the ICA, where the vessels change direction, passing on the insula and ascending. The position of the receptor vessel is also very important. The more superficial it is, the easiest the suture will be. The craniotomy is planned according to this anatomical situation of the MCA branches.

The branches of the main division of the MCA have an adequate calibre and a superficial position, and they are not related to the perforating vessels. Due to these characteristics it is possible to clamp those vessels with low risk of ischemia in the corresponding territory. All the branches of the MCA after the main bifurcation (M2) are long enough for an anastomosis. Sundt et al.[30] considered the superior branch the most suitable for an anastomosis. But, the superior branch is responsible for the irrigation of the precentral and postcentral giri. The inferior branch is also adequate to the suture, and it would carry a lower risk of neurological deficit. The angular artery originates from the inferior branch. This artery is not as calibrous as the branches from the main division, but it is more superficial. It carries low risk of neurological deficit, if the anastomosis is performed in the non dominant cerebral hemisphere.

In conclusion, performing an anastomosis between the external carotid artery and calibrous branches of the MCA, using vein graft, is an important alternative to preserve the blood flow in the MCA territory. This technique allows a radical removal of skull base tumours, that infiltrate the internal carotid artery. It permits the management of giant aneurysms of the ICA and MCA. The superior and inferior branches from the main division of the MCA are suitable for the anastomosis

REFERENCES

1. Allcock JM Occlusion of the middle cerebral artery: serial angiography as a guide to conservative therapy. J Neurosurg 1967;27:353-363.
2. Anderhuber F, Weiglein A, Pucher RK. Über Trifurkationen der Arteria cerebri media. Acta Anat 1990;137:342-349.
3. Antunes ACM Contribuição ao estudo microcirúrgico da artéria cerebral média humana. Arq Bras Neurocirurg 1985;4:195-208.

4. Brown WE Jr, Ansell LV, Story JL. The technique of saphenous vein bypass graft from the common carotid artery to the middle cerebral artery. In Erickson DL (ed). Revascularization for the ischemic brain. Mount Kisco NY: Futura, 1988:167-199.
5. Conley JJ. Free autogenous vein graft to the internal and external carotid arteries in the treatment of tumors of the neck. Ann Surg 1953;137:205-214.
6. Gibo H; Carver CC; Rhoton AL et al. Microsurgical anatomy of the middle cerebral artery. J Neurosurg 1981;54:151-169.
7. Glasscock ME III, Smith PG, Bond AG et al. Management of aneurysms of the petrous portion of the internal carotid artery by resection and primary anastomosis. Laryngoscope 1983;93:1445-1453.
8. Grand W. Microsurgical anatomy of the proximal middle cerebral artery and carotid bifurcation. Neurosurgery 1980;7:215-218.
9. Irino T, Taneda M, Minami T. Sanguineous cerebrospinal fluid in recanalized cerebral infarction. Stroke 1977;8:22-24.
10. Kitame K, Tsuchida H, Sohma T, Hamajima I, Sakamaki Y, Takeda T. Emergency embolectomy in embolic occlusion of the middle cerebral artery. No Sinkei Geka 1988;16:977-982.
11. Krayenbuhl HA, Yasargil MG. Occlusion of the middle cerebral artery. Schweiz Arch Neurol Psychiat 1964;94:287-304.
12. Little JR, Furlan AJ, Bryerton B. Short vein grafts for cerebral revascularization. J Neurosurg 1983;59:384-388.
13. Marinkovic SV, Kovacevic MS, Marinkovic JM. Perforating branches of the middle cerebral artery. Microsurgical anatomy of their extracerebral segments. J Neurosurg 1985;63:266-271.
14. Marrone ACH, Severino AG. Insular course of the branches of the middle cerebral artery. Folia Morphologica 1988;36:331-336.
15. Meneses MS, Molinari D, Fortes M et al. Surgical considerations about the anterior syphon knee of the internal carotid artery: an anatomical study. Arq Neuropsiquiatr 1995;53:34-37.
16. Meyer FB, Piepgras DG, Sundt TM Jr,Yanagihara T Emergency embolectomy for acute occlusion of the middle cerebral artery. J Neurosurg 1985;62:639-647.
17. Opalak ME, Chehrazi BB, Boggan JE Emergency intracranial tromboendarterectomy for acute middle cerebral artery embolus. Microsurgery 1988;9:188-193.
18. Ramina R, Arruda WO, Prestes ACF, Parolin MKF, Teive H, Meneses MS Arterial graft reconstruction in an aneurysm of the middle cerebral artery. Neurosurgery 1990;26:327-329.
19. Rosner S, Rhoton AL Jr, Ono M et al. Microsurgical anatomy of the anterior perforating arteries. J Neurosurg 1984;61:468-485.
20. Sampson DS, Gewert BL, Beyer CW et al. Saphenous vein interposition grafts in the microsurgical treatment of cerebral ischemia. Arch Surg 1981;116:1578-1582.
21. Sekhar LN. Vein graft replacement of the middle cerebral artery after unsuccessfull embolectomy: case report. Neurosurgery 1993;33:723-727.
22. Sekhar LN. Cerebral revascularization using venous graft (Lecture). Hospital das Nações, Curitiba, Brazil 1995, September.
23. Sen C, Sekhar LN. Direct vein graft reconstruction of the cavernous, petrous, and upper cervical internal carotid artery: lessons learned from 30 cases experimental and clinical study. Neurosurgery 1992;30:732-743.
24. Spetzler RF, Comments on Diaz FG , Pearce J, Ausman JI. Complications of cerebral revascularization with autogenous vein grafts. Neurosurgery 1985;17:271.
25. Spetzler R, Chater N. Microvascular bypass surgery. J Neurosurg 1976;45:508-513.
26. Spetzler RF, Fukushima T, Martin N, Zabramski JM. Petrous carotid-to-intradural carotid saphenous vein graft for intracarvenous giant aneurysm, tumor, and occlusive cerebrovascular disease. J Neurosurg 1990;73:496-501.
27. Spetzler RF, Rhodes RS, Roski RA, Likavec MJ Subclavian to middle cerebral artery saphenous vein bypass graft. J Neurosurg 1980;53:465-469.
28. Spetzler RF, Selman WR, Roski RA, Bonstelle C Cerebral revascularization during barbiturate coma in primates and humans. Surg Neurol 1982, 17:111-115.
29. Story JL, Brown WE, Eidelberg E, Arom KV, Stewart JR. Cerebral revascularization: common carotid to distal middle cerebral artery bypass. Neurosurgery 1978;2:131-135.
30. Sundt TM Jr,Piepgrass DG, Marsh WR, Fode NC. Saphenous vein bypass grafts for giant aneurysm and intracranial occlusive disease. J Neurosurg 1986, 65:439-450.
31. Swan KW, Heros RC, Debrun G, Nelson C Inadvertent middle cerebral artery embolism by a detachable balloon: management by embolectomy. Case report. J Neurosurg 1986;64:309-312.
32. Umansky F, Dujovny M, Ausman JI et al. Anomalies and variations of the middle cerebral artery: a microanatomical study. Neurosurgery 1988;22: 1023-1027.
33. Umansky F, Juarez SM, Dujovny M et al. Microsurgical anatomy of the proximal segments of the middle cerebral artery. J Neurosurg 1984;61:458-467.
34. Welch K Excision of occlusive lesions of the middle cerebral artery. J Neurosurg 1956;13:73-80.
35. Yoshimoto T, Ogawa A, Seki H, Kogure T, Suzuki J Clinical course of acute middle cerebral artery occlusion. J Neurosurg 1986;65:326-330.