CONTEMPORARY INDICATIONS AND OWN RESULTS OF SURGICAL TREATMENT OF OCCLUSIONS OF THE INITIAL SECTION OF THE LEFT SUBCLAVIAN ARTERY

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Symptomatic occlusion of the initial section of the subclavian artery, resistant to intravascular treatment, is an indication for a surgery as it exacerbates the vertebrobasilar insufficiency and creates the risk of peripheral embolism. Reconstructive surgery fixes the reversed blood flow in the vertebral artery, alleviates neurological and limb ischemia symptoms.

The aim of the study was to retrospectively evaluate the results of surgical treatment of the occlusion of the initial section of the subclavian artery using transposition or subclavian-carotid by-pass with a PTFE.

Material and methods. Retrospective analysis covered 55 patients operated on between June 1996 and August 2008 for occlusion of the left subclavian artery. 39 patients underwent a subclavian artery transposition (SCT) and the remaining 16 had a subclavian-carotid by-pass (SCB) using a PTFE. Indications for surgery included ischemic symptoms in the upper limb and impaired vertebrobasilar circulation. Clinical symptoms occurred in the following order: vertebrobasilar insufficiency and upper limb ischemia (62%), upper limb ischemia symptoms (22%), vertebrobasilar insufficiency (16%).

Results. There were no early deaths (by day 30). Ischemia was lifted in 100% of the patients operated using transposition and in 93% of those with a by-pass. In the perioperative period, one patient had a bypass thrombosis, and 2 patients had a transitional brain ischemia. These incidents affected patients who underwent subclavian-carotid by-pass. In the late postoperative period, 12 patients (21.81%) died due to cardiological complications and 7 patients (12.72%) for other causes, and none of them was related to the primary surgery. All patients with transposition have maintained the primary patency, with average follow-up period of 73 months (23-138). In the group with a by-pass, occlusion occurred in 3 patients in the first follow-up month. These incidents had no effect on survival rates. For the remaining 14/16 patients from the SCB group the average primary patency was 63.4 (8-104) months.

Conclusions. Subclavian-carotid transposition is a safe and effective method of upper limb revascularization. It is technically more difficult than the by-pass but ensures a better short-term and long-term result.

Key words: subclavian steal syndrome, subclavian-carotid transposition, subclavian-carotid by-pass

Critical constriction of the aortic arch branches or their complete occlusion are diagnosed in a small percentage of patients referred for precerebral arteries examinations (1). This is affected by a large possibility of collateral circulation development and by only a slight reduction of the patients’ quality of life (2). The constriction is usually caused by the developing atherosclerotic plaque, the development of which in this area is characterized with a small growth rate. Therefore, and due to the significant risk, conventional surgeries on aortic arch branches have until recently been allowed to be performed only on patients with very intensive ischemic symptoms. They accounted for as little as 10% of symptomatic patients (3, 4). Nowadays, the dynamic growth of surgical radiology allowed the development
of a low invasive, endovascular alternative for the hazardous conventional surgeries (5). Angioplastics of arteries with stent implantations are commonly successfully performed, in particular in the constricted areas or in the areas with „fresh” thromboses. This resulted in extension of the indications and increase in the intervention rate, as well as in reduction of the number of conventional surgeries on the aortic arch branches.

There are, however, cases resistant to endovascular therapy, in which an open surgery remains the only solution. These include: occlusion of the initial section of the subclavian artery that cannot be resolved with a stent and the ostium of the left subclavian artery closed with stent grafting used in treatment of the increasingly common injuries or aneurysms of descending thoracic aorta (1).

The many methods of restoring patency of the initial section of the subclavian artery include: subclavian-carotid bypass or thrombendarterectomy with chest opening (6), subclavian-carotid transposition or various types of prosthetic grafts (7). Gaining access to the left subclavian artery by thoracotomy is a procedure hazardous for the patient, and is characterized by a large rate of complications and deaths. Thus, such procedures have been performed very rarely in the recent years. The most frequently and willingly performed restorative surgery on an occluded subclavian artery is therefore its transposition (SCT) and less frequently – the subclavian-carotid bypass (SCB) from a PTFE (8, 9).

The aim of this paper was to retrospectively evaluate the results of surgical treatment of the occlusion of the initial section of the subclavian artery using transposition or subclavian-carotid by pass with a PTFE.

MATERIAL AND METHODS

Retrospective analysis covered 55 patients (33 men and 22 women) in whom the surgical treatment was indicated by the occlusion of the initial section of the left subclavian artery with very intensive clinical ischemic symptoms in the upper limb and/or vertebrobasilar insufficiency. 34 (62%) of the patients had upper limb ischemia symptoms as well as vertebrobasilar insufficiency symptoms. Another twelve (22%) patients had upper limb ischemia symptoms, while the remaining 9 (16%) had ischemic symptoms in the posterior cerebral and cerebellar region.

Table 1 presents the characteristics of the operated patients. The mean age was 68 (51-75 years). The material included patients treated between May 1996 and August 2008. The cause of artery closure was atheromatous plaque (53 cases) or thoracic stent graft covering the inlet of the left subclavian artery (2 cases).

The disease was diagnosed based on a clinical examination with a color-coded Doppler ultrasound and DSA angiography or CT angiography of the aortic arch. In the duplex-Doppler ultrasound the direction of blood flow in the vertebral artery was examined. If the blood flow in the vertebral artery was bidirectional or reversed, the flow spectrum in the homonymous subclavian or axillary artery would be additionally examined to allow differentiation between an occlusion or a major constriction of the proximal artery. In ambiguous cases, e.g. when the flow spectrum in the vertebral artery suggested 1st degree subclavian steal syndrome, the diagnosis would be specified using the passive hyperemia test in the limb. 52 patients had a permanent and 3 had a temporary reverse blood flow direction.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>SCB n</th>
<th>SCT n</th>
<th>Total n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypercholesterolemia</td>
<td>11 (68,7%)</td>
<td>24 (61,5%)</td>
<td>35 (63,6%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>14 (87,5%)</td>
<td>20 (51,2%)</td>
<td>34 (61,8%)</td>
</tr>
<tr>
<td>Inschemic atherosclerosis in the limbs</td>
<td>16 (100%)</td>
<td>11 (28,2%)</td>
<td>27 (49%)</td>
</tr>
<tr>
<td>Coronary insufficiency</td>
<td>14 (87,5%)</td>
<td>7 (17,9%)</td>
<td>21 (38,2%)</td>
</tr>
<tr>
<td>Cerebral vascular insufficiency</td>
<td>9 (56,25%)</td>
<td>5 (12,8%)</td>
<td>14 (25,5%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>4 (25%)</td>
<td>7 (17,9%)</td>
<td>11 (20%)</td>
</tr>
<tr>
<td>Chronic renal failure</td>
<td>4 (25%)</td>
<td>2 (5,3%)</td>
<td>6 (10,9%)</td>
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</table>
related to exertion. Angiography in all patients has shown occlusion of the initial subclavian artery, and 6 of them had a comorbid critical constriction of the internal left carotid.

The patients would be qualified for a surgery based on the following criteria: limping of the upper limb to the extent impeding daily functioning, with an absence of pulse on the radial artery, and symptoms of vertebrobasilar insufficiency with disturbed balance and falls confirmed in the neurological assessment.

In 39/55 (70.9%) cases subclavian-carotid transposition (SCT) was performed. Surgery in this group was supplemented with patency restoration in the internal carotid in 2 (5.5%) patients, and in 7 (20.6%) patients with patency restoration in the distal section of the removed subclavian artery, and in 3 (8.8%) patients with thyreocervical trunk ligation, in 1 patient with lymphatic duct ligation. 16/55 (29%) patients had a subclavian-carotid by-pass from a PTFE (SCB). In this group, 4 patients (25%) had additionally patency in the internal carotid restored and 1 patient had lymphatic duct ligated (see tab. 2). Selection of the operating method depended on technical possibilities, e.g. in the case of early branching-off of the vertebral artery or using internal thoracic artery in coronary by-pass (impeding mobilization of the subclavian artery) the bypass was performed from a prosthesis. In three patients, artery transposition was abandoned due to the previous revascularization treatment on the heart using internal thoracic artery, while in 13 patients it was abandoned due to an anatomic variation consisting in an early branching-off of the vertebral artery from the subclavian artery.

All patients were operated on in general anesthesia. The surgery was performed with the patient in supine position with a roll under the left shoulder and head rotated in the opposite direction. The incision line ran around 2 cm above the clavicle’s edge. Following incision of the skin and platysma, the access between the sternocleidomastoid (SCM) muscle insertions would be selected. Then the „fat pad” would be separated to expose the underlying anterior scalene muscle. Making effort to secure the phrenic nerve against damage, the scalene muscle would be cut to expose clearly the subclavian artery with its branches: thyreocervical trunk and the internal thoracic and vertebral arteries. Particular attention would be paid to preparing the proximal subclavian artery and separating the surrounding tissues. Exposure of a long section of an artery facilitated the subclavian-carotid connection under the SCM muscle and internal carotid without stretching and folding the outgoing arterial branches. The subclavian artery stump would be dressed with a continuous stitch using Prolene 4-0 sutures.

Results of the procedure were evaluated at the patient’s discharge and in long-term period. Follow-up studies were performed after 1, 3 and 6 months and then in annual intervals. The mean follow-up period for the SCT patients would be 73 months (23-138) while in the bypass group – 63.4 (8-104) months. Patency of the performed arterial connections were confirmed by pulse examination on the radial artery. In ambiguous cases, duplex-Doppler ultrasound was performed to evaluated blood flow. Note that the easiest objective method of checking efficacy of the surgery is periodical check of blood flow in the homonymous vertebral artery. Gradual reduction of the cephalad flow rate or occurrence of bidirectional flow is a sensitive indicator of restenosis growth in the connection. The result was deemed positive if the preoperative symptoms of cerebral circulation insufficiency and/or circulation insufficiency in the upper limb were lifted. The result was deemed negative if the symptoms recurred or occlusion in the connections occurred.

Statistical analysis, using the Kaplan-Meier’s method, was used to compare both groups in terms of survival rates. The long-

<table>
<thead>
<tr>
<th>Incident type</th>
<th>SCB</th>
<th>SCT</th>
<th>Ogółem / Total</th>
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</thead>
<tbody>
<tr>
<td>Lymphatic duct ligation</td>
<td>1/16</td>
<td>1/39</td>
<td>2/55 (3,6%)</td>
</tr>
<tr>
<td>Thyreocervical trunk ligation</td>
<td>0</td>
<td>3/39</td>
<td>3/55 (5,4%)</td>
</tr>
<tr>
<td>Patency restoration in the internal carotid artery</td>
<td>4/16 (25%)</td>
<td>2/39 (5,5%)</td>
<td>6/55 (10,9%)</td>
</tr>
<tr>
<td>Patency restoration in the subclavian artery</td>
<td>0</td>
<td>7/39</td>
<td>7/55 (12,7%)</td>
</tr>
</tbody>
</table>

Table 2. Intraoperative incidents in patients operated on using the subclavian-carotid by-pass (SCB) and subclavian-carotid transposition (SCT)
rank test compared the statistical significance of differences in the graph lines for both groups (10). The statistical relevance level was < 0.05. The statistical calculations were made using a statistical software application – STATISTICA for Windows ver. 6.0 (Microsoft®, US).

RESULTS

No deaths in either of the surgery groups were noted in the perioperative period. In 2/16 (12.5) cases following a subclavian-carotid bypass in Day 1 following the surgery transitional brain ischemia symptoms were observed, while the prosthesis remained patent. In one patient (6.2%) from the same group, the bypass thrombosis occurred, although there were no brain ischemia symptoms. The remaining 13/16 patients (81.2%) with a bypass reported no complaints. In the group operated on using the transposition method, the check X-ray in the postoperative period has shown elevated left phrenic dome in one patient (1/34; 2.9%) symptomatic of the phrenic nerve damage. The above did not cause any tangible clinical sequelae. All patients in this group had the pulse on the radial artery restored and the brain and/or upper limb ischemia symptoms were lifted. Due to technical difficulties, 2/24 (5.4%) of the patients with transposition performed, also the thyreocervical trunk was ligated during the surgery. In another 2/55 (3.6%) patients (one from each of the groups), the lymphatic duct was ligated. Neither thyreocervical trunk or lymphatic duct ligations caused any complaints. Additionally, in two patients (one from each of the groups), hematomas in the postoperative wound, not requiring revision, occurred in Day 1 following the surgery. Early postoperative complications were noted in the total of 6/55 (10.9%) of the patients (tab. 3).

In long term, 2 patients (3.6%) from the SCB group had ischemic symptoms in the posterior cerebral and cerebellar region. This was due to coagulation in the subclavian-carotid bypass. These patients were operated on for symptoms of the vertebrobasilar insufficiency but due to slight ischemic symptoms they would not undergo another restorative surgery. In long term follow-up in both groups, 19 patients (34.54%) died but the deaths were unrelated to the surgical procedure. The mean survival rate in the SCT group was 73 months (23-238) while in the SCB it was 63.4 months (8-104) (p=0.241). In the SCB group, loss of primary patency occurred in Month 1 of the follow-up in three patients. In the remaining study patients from this group, the primary patency persisted until the time of death. Comparative analysis of both groups in terms of survival rate and primary patency has shown no statistically significant differences. Figure 1 shows the cummulated survival rate for both study groups.

DISCUSSION

Although there are reports on the small need to revascularize the aortic arch branch,

<table>
<thead>
<tr>
<th>Incident type</th>
<th>SCB</th>
<th>SCT</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>TIA</td>
<td>2/16 (12,5%)</td>
<td>0</td>
<td>2/55 (3,6%)</td>
</tr>
<tr>
<td>Phrenic nerve damage</td>
<td>0</td>
<td>1/34 (2,9%)</td>
<td>1/55 (1,8%)</td>
</tr>
<tr>
<td>Hematoma in the postoperative wound</td>
<td>1/16 (6,25%)</td>
<td>1/34 (2,9%)</td>
<td>2/55 (3,6%)</td>
</tr>
<tr>
<td>By-pass thrombosis</td>
<td>1/16 (6,25%)</td>
<td>0</td>
<td>1/55 (1,8%)</td>
</tr>
</tbody>
</table>

Fig. 1. Comparison of survival rates of both study groups: subclavian-carotid by-pass (SCb) and subclavian-carotid transposition (SCT)
restoration of blood flow in arteries supplying the head and upper limbs seems by all means necessary in some cases (1). This applies mainly to patients with a symptomatic closure of the subclavian artery.

Contemporary references on revascularization of the aortic arch branch increasingly often note the growing importance of angioplasties and artery stenting as procedures easier than the conventional restorative surgeries, low invasive and currently treated as the treatment of choice (11). Patients who can qualify for endovascular procedures include mainly patients with soft atheroma through which the guide can be introduced to perform the angioplasty. Similar criterion was adopted by the authors hereof, qualifying for conventional surgeries only those patients in whom the endovascular procedure was impossible to perform.

Another cause of closure of the initial section of aortic arch arteries requiring surgical interventions are complications following endovascular surgeries on aortic aneurysms or aortic wall dissections. This is mainly the case with Standford type B aortic dissections which can result in upper limb ischemia following covering of the left subclavian artery inlet with a stent graft (12). The authors of this paper, performing endovascular procedures, in 30 cases of subclavian artery inlet closure observed limb ischemia symptoms requiring surgical restoration of arterial blood supply in only 2 patients (6.7%). These patients were also included in this study. Our observations corroborate with experience of other authors who observe the need of limb revascularization in similar cases extremely rarely (9). On the other hand, there are researchers who based on postoperative analysis claim that in long-term follow-up only 25% of the patients who underwent such surgeries had no signs of chronic ischemia (7, 8). These differences may result from a different approach to quality of life assessment in patients with an occlusion in the initial section of the left subclavian artery. It seems that this is to give opinion in the discussion on extending indications for surgical revascularization of the left upper limb.

It is currently unquestioned that the occlusion of the initial section of the aortic arch arteries resistant to endovascular treatment in patients with symptomatic subclavian steal syndrome requires a conventional surgery (1, 4). It consists in transposing the subclavian artery to the internal carotid or inserting a subclavian-carotid by-pass from a prosthesis (13, 14). In spite of the increased risk of this surgery compared to endovascular procedures, performing a conventional surgery additionally allows simultaneous permanent solution of the comorbid critical obstructions in the internal carotid. This is corroborated by the observations made in 6 of our patients (4 from the SCB group and 2 from the SCT group) in whom a successful patency restoration in the left internal carotid was performed simultaneously yielding a lasting hemodynamic result.

Similar opinion has been expressed also by authors from the Virginia University (1) who restored patency in the critically constricted internal carotids while creating the subclavian-carotid by-pass. Moreover, the above-mentioned authors reported a high total rate of primary and secondary patency following SCB, which in 1, 3, 5 and 10-year follow-up amounted to, respectively, 100%, 98%, 96%, 92% and 100%, 98%, 98%, 95%. The presented results differ only slightly from the results of endovascular methods of treating simple arterial constrictions, and in addition yield better long-term results (1, 16). For instance, in the paper by Schillinger et al. (17), covering 107 subjects with previous endovascular interventions on the subclavian artery, the patency rate after 1 year, 3 and 4 years remained, respectively, on the level of 91%, 83%, 79%. In our own study, the primary patency in the follow-up period after 1 year, 3 and 5 years was 68% for SCB and 100% for SCT. Our results are therefore worse than the ones quoted above which may result from the generally worse condition of the patients at the time of surgery. In the presented material, only one patient suffered from an early occlusion, in the remaining patients the primary patency time was as long as the time of survival.

An observation common for the quoted authors following restorative surgeries of the subclavian artery occlusions was that the preoperative complaints subsided immediately. This proves the that the chosen treatment method was appropriate and effective (13). Also in the present paper we have noted immediate subsidence of complaints in nearly all patients from both groups. An exception included two patients from the SCB group who
in Day 0 suffered from TIA symptoms which, however, caused no permanent morphological changes or brain function deficits. This is probably due to the comorbid disseminated lesions in the intracranial vessels.

Paper authors accessed the operating site over the left clavicle between the sternal and clavicular insertions of the SCM muscle. As opposed to the observations of Domenig at el. (8) we did not differentiate between the medial and lateral access. To obtain a better insight into the operating field, we would cut the anterior scalene muscle thus achieving a free mobilization of the subclavian artery with its branches. Subclavian-carotid transposition was the preferred method which in our opinion is more reasonable because of the need to perform only one connection between arteries. In the material of the authors hereof, such a surgery was performed on 39/55 patients (70.9%) yielding 100% primary patency.

Validity of the method selection is confirmed also by the relatively small rate of postoperative complications which in the authors’ material amounted to 10.9%. In 2 cases, complication sequelae were permanent. One patient had a by-pass thrombosis. It should be noted that he had dominant vertebrobasilar insufficiency symptoms and a comorbid critical constriction of the internal carotid artery. The patient did not consent to another surgery. He died after 8 months of outpatient follow-up and his clinical image presented a cerebral stroke. The other patient, in turn, reported no complaints however the postoperative X-ray check has shown a left diaphragmatic dome elevation which might have resulted from the iatrogenic nerve damage. The other postoperative complications subsided completely.

Also the information of Abu Rahma et al. (1) are worth noting. The quoted authors prefer subclavian-carotid bypass from a PTFE prosthesis in treating symptomatic subclavian steal syndrome. Surgical treatment of symptomatic closures of the subclavian artery conforms with the views of most authors who consider subclavian-carotid transposition and/or bypass the methods of choice giving excellent multiannual patency. Death rate until Day 30 following the surgeries varies in studies by various authors from 0 to 6% (1, 8). This large range of the observed incidents undoubtedly should be associated with the patients’ condition prior to the surgery. This is corroborated by patient characteristics presented by the quoted authors where each group included more than 50% of cases of comorbid ischemic atherosclerosis of the limbs, diabetes or hypercholesterolemia (1, 8, 18). This fact undoubtedly affects the long-term results reported by most of the researchers which allow tracking of the patients’ death rate due to the causes presented above. The authors hereof treated 55 patients whose follow-up period was from 8 to 138 months, mean was 69.6. Curve on the Kaplan-Meier's chart indicates a gradual loss of patients following 60 months of the follow-up, mainly in the patients from the subclavian-carotid by-pass group. This can be explained with exacerbation of comorbid conditions, leading to death caused by the myocardial infarction or cerebral stroke (19). In the long-term follow-up period, 12 patients (21.81%) died due to cardiological complications and 7 patients (12.72%) for other causes, and none of them was related to subclavian-carotid transposition or by-pass.

CONCLUSIONS

1. Subclavian-carotid transposition is a safe and effective method of upper limb revascularization.
2. Transposition is technically more difficult than the by-pass but ensures a better short-term and long-term hemodynamic result.

REFERENCES


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