Intraoperative Carotid Artery Injuries. Review of the literature, analysis of the material of one centre

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ABSTRACT: Injuries of the carotid artery constitute a rare group of injuries. This study presents results of the treatment of 44 patients with iatrogenic carotid artery injuries for over 20 years. The patients were treated by the team of doctors of the Department of Vascular, General and Transplant Surgery in Wroclaw in the years 1997–2017 (Head of the Department Prof. Klemens Skóra, MD, and Prof. Piotr Szyber, MD, PhD – material used with permission).

Aim: Aims of the analysis are: to estimate the frequency of different forms of iatrogenic injuries to the common and internal carotid artery, to evaluate the results of treatment, to assess the most effective surgical method depending on the type of injury, and to develop an effective preoperative, intraoperative and postoperative regimen.

Discussion and results: The frequency of various carotid artery injuries (blunt, acute, traffic) was constant between years, but the number of iatrogenic injuries definitely increased over time. The prognosis for patients with carotid artery injury, especially when combined with multi-organ trauma, is the gravest. Significantly better treatment results were achieved with both acute and iatrogenic injuries. This is mainly due to easier and quicker diagnosis and better conditions for assisting patients.

Conclusions: In iatrogenic injuries, a well-designed surgical scheme, i.e. primarily the administration of UTH and placing a temporary suction drain by the first operating team, reduces the risk of neurological complications.

KEYWORDS: carotid artery injury, iatrogenic carotid artery injury

ABBREVIATIONS

CCCA – common carotid artery
CNS – central nervous system
DD – duplex Doppler
ECA – external carotid artery
ICA – internal carotid artery
TIA – transient ischaemic attack
TND – transient neurological deficit
UFH – unfractionated heparin

Carotid artery injuries during times of peace are a relatively rare group of arterial injuries. Carotid artery injuries are thought to account for approximately 5% of all arterial injuries [1, 2] and 0.2–0.5% of all bodily injuries. However, relatively numerous reports in available literature show an increase in frequency. In particular, the number of reported blunt injuries is growing. According to Fabian et al., 96 cases were reported until 1980, 75 cases in the 1980s and from 1990 to 1995 there were already 309 published cases [3]. In an epidemiological study of cardiovascular injuries carried out between 1958 and 1987, Mattos et al. analysed 4459 cases. Based on published data, the incidence of carotid artery injury was estimated at 3.3% [4].

Two factors, in particular, appear to be responsible for the increasing number of blunt injuries, namely the increased leisure time sports activities and the growing mobility of people, associated with the intensive use of means of transport and thereby accidents with the resulting hyperextension of the cervical spine [5]. Diagnosis, especially in relation to head trauma, is not so simple due to the ambiguous yet multicoloured clinical picture. It is especially not simple to quickly identify the reason why the patient is unconscious [3]. Only a thorough analysis of the test results and consultation by an experienced doctor can guide to the correct diagnosis [6]. Priority dictates the diagnostics and supply of cerebral arterial blood [7].

A much more rapid diagnosis of carotid artery injury can be made in isolated cuts, stab wounds, incised wounds and iatrogenic injuries. Failure to control bleeding from a vessel with a flow of 10% of cardiac output regrettably all too often results in death [1].

Inflow failure, resulting from intraoperative bleeding and the interruption of blood flow, can cause serious complications, including neurological ones. They include hypotension, hypovolaemic shock and reduced cerebral perfusion, leading to the ischaemia of the entire central nervous system (CNS). For this reason, it is crucial to introduce appropriate methods with standardised management [3, 6]. In the event of intra-operative major injuries to arteries, their managing is a crucial task for an experienced vascular surgeon [2]. Such an injury to the carotid artery can occur during various neck procedures, e.g. large vein puncture, cerebral angiography, percutaneous treatment of trigeminal neuralgia, tracheostomy, middle ear surgery, tumour removal, surgery at the base of the skull [8].

The rapid development of modern medicine, in particular diagnostics, anaesthesiology and surgery, allows for major and more complex surgical interventions [9]. The same also applies to surgery for neck tumours. Modern surgical techniques permit widening the indications for surgical intervention, to include such diseases and lesions which were recently considered inoperable, and their location was
a contraindication to surgery [10]. Any procedure connected with a neck tumour, regardless of its aetiology, can cause damage to the carotid artery, with subsequent massive haemorrhage and severe neurological complications.

The early history of diagnosis and treatment of carotid artery injury is long, but the history of its treating, and especially successful treating, is much shorter.

Hippocrates (460–377 BC), one of the most famous physicians and thinkers of the ancient world, described the occlusion of an artery and a stroke that caused paralysis. He noted that symptoms occurred on the opposite side of the body to the injury [11]. Only many centuries later, after more detailed anatomical studies, Andreas Vesalius (1514–1560), Ambroise Paré (1510–1590) and Johann Jakob Wepfer (1620–1695) demonstrated that damage to or thrombosis of the carotid artery causes cerebral ischaemia [12]. Wepfer also introduced the term transient cerebral ischaemic attack (TIA) [13].

In all previous reports in available literature, therapeutic methods were not presented; however, it has been shown that stroke is definitely associated with direct carotid artery injury or occlusion.

The history of surgical interventions on the carotid artery and the first case reports of patients on the subject did not appear until the 18th century. The enormous number of patients was the product of countless wars and battles with sharp weapons (swords, bayonets, knives, etc.). The first surgical procedures that provided knowledge of carotid artery injury showed little technical capability and were limited to ligation of the bleeding vessel. Extensive reports on carotid artery ligation, as well as a description of the results in Germany, are due to E. B. G. Hebenstreit in 1793 and in England to Sir J. Abernethy in 1798 [14, 15]. A surgical procedure of iatrogenic injury of the common carotid artery (CCA) was carried out by Benjamin Bell in 1793. During removal of the CCA tumour, the artery was injured, but the treatment itself was limited only to ligation of the artery. The patient survived for many years after surgery without complications [16].

In 1803, Manson F. Cogswell performed the first carotid artery ligation in the US and documented it in 1824. A 38-year-old patient had a tumour removed that had grown together with the carotid artery. The tumour was removed and the artery ligated. The patient died 20 days after surgery as a result of bleeding. Cogswell, as he described it, recognised technical limits when separating a tumour – it is inoperable if it is associated with an artery [17].

Amos Twichell, also from the US, successfully ligated the carotid artery in 1807 in a 20-year-old soldier with a gunshot wound in the neck region. Twichell compressed the CCA and then dissected and ligated it. He was surprised to find retrograde internal carotid artery (ICA) bleeding after ten days. In these circumstances, he decided to proceed with treatment with another compression. The bleeding stopped and the wound healed by granulation. Twichell presented the entire procedure 35 years later, in 1842 [18, 19].

Between 1916 and 1921, several publications reported the successful repair of carotid artery injuries due to trauma in the course of or after tumour removal [12]. In 1918, LeFevre in France published a case report of a surgical anastomosis of the distal end of the ICA with the external carotid artery (ECA) [20]. The same method, applied after resection of the tumour including artery, was used by John Conley in 1952. A year later, he presented eleven instances of transplantation from the saphenous vein or superficial femoral vein after resection of the carotid artery, including the tumour [21].

A clear division of vessel wall injuries was given by Linder and Vollmar in 1965:

- Stage I: damage to the inner membrane;
- Stage II: damage to the internal and medial membrane;
- Stage III: injury to all three layers of the artery with occlusion by a thrombus.

Through blunt trauma, the vessel wall is damaged from inside to outside. Pressure or stretching, including intraoperative, results in rupture of the inner membrane, its detachment and finally, its protrusion and the formation of a closing thrombus.

Acute wounds, such as cuts or puncture wounds, including iatrogenic wounds, can lead both to damage to the outer layer of the artery (the adventitia) as well as penetrate deeper, damaging and cutting through all three layers of the vessel. Linder and Vollmar introduced in 1965 [22] a distinct three-stage division of acute arterial injuries:

- Grade I: damage to the vessel without opening the lumen;
- Grade II: partial transection of the vessel wall;
- Grade III: complete transaction.

The most severe consequence is acute cerebral ischaemia, with highly variable symptoms, also conditioned by intraoperatively unrecognized trauma, which also depends on compensatory mechanisms. A large postoperative haematoma that compresses the carotid artery can lead to a cessation of bleeding, but at the same time, can cause airway obstruction [22].

Iatrogenic carotid artery injuries represent relatively rare complications [23, 24]. However, with increasingly complex surgical interventions in the neck area, their number is steadily increasing. They include thyroid operations or oncological interventions to remove tumours growing in the arterial region that are displacing or even infiltrating it [23]. Technical problems with tumour preparation are enhanced by the possibility that certain types of tumour have their vascular system and infiltrate the arterial wall. A classic example is a paraganglioma (chemodectoma, tumour of the carotid glomus).

Fig. 1. Three forms of growth of glomus tumour of the carotid artery bifurcation, according to Linder [22].

- TYP I
- TYP II
- TYP III
This tumour, arising from the peripheral nervous system, is histologically and cytologically neuroendocrine [24, 25].

By localizing and expanding in the CCA bifurcation, the glomus tumour causes the bifurcation to take on a classic lyre shape. On the one hand, it widens it, and on the other, it covers the arteries. During the development of an advanced stage tumour, iatrogenic damage to the arterial wall can occur relatively easy. Linder, in 1953, introduced the classification of tumour forms [24], which was modified in 1971 by Shamblin [22, 26]. This division distinguishes three clinical tumour forms relevant to surgical management (Fig. 1.):

- **Type I:** A simple dissection of the tumour with the capsule is possible without damage to the vessel (26%);
- **Type II:** Tumour partially involves an artery; dissection without damage to the vessel wall is difficult (approximately 46.5%);
- **Type III:** The bifurcation of the common artery is fully covered by the tumour so that it is almost impossible to remove it without simultaneous resection of the arterial segment (approximately 27.5%).

To properly assess the anatomy of the area, especially the pattern of vascular involvement, prior ultrasound and duplex Doppler (DD) ultrasound are necessary. DD ultrasonography is particularly adequate as a screening method, and a correct diagnosis can be established in almost 100% of cases [27, 28]. Classic angiography is not recommended because of possible complications. However, it can be combined with a tumour embolization, recommended as a pre-operative procedure by a limited number of authors.

For neck tumours’ identification, it is a biopsy that is often used as part of the diagnosis. However, given the specific anatomy of the carotid glomus tumour, severe complications are to be expected if a biopsy is performed. Namely, during the procedure, the artery is easily damaged [29–33]. Moreover, according to one group of authors, a biopsy can also lead to further tumour growth and even cause malignant degeneration. For these reasons, sampling by excision is contraindicated in cases of suspected glomus tumours [32, 34].

The literature further describes numerous iatrogenic carotid artery injuries in intensive care settings. When providing venous access, there is an increased risk of incorrect placing of the central line and damage to the ACC, obstruction, thrombus and even embolic stroke [33, 34].

Given the relatively low frequency of diagnosed carotid artery injuries, the technical challenges associated with their treatment, the high demands on the treating physician and the small number of published papers on the subject – we decided to analyse the material of patients treated in a vascular surgery centre [36].

The material was obtained from the population of patients treated in the Department of Vascular, General and Transplant Surgery led by Prof. Klemens Skóra, MD, and later by Prof. Piotr Szyber, MD, and thus from an emergency centre for a large region (Lower Silesia) with 3.5 million inhabitants. The analysis aims to:

1. Assess the prevalence of different forms of iatrogenic carotid artery injury;
2. Evaluate and assess the results of the therapy;
3. Evaluate and assess the most effective way to approach the patient and develop the most effective treatment regimen.

**PATIENTS**

For the present study, 73 patients with carotid artery injuries were analyzed. The patients were treated at the Department between 1997 and 2017. According to available data, approximately 1,200 vascular operations were performed annually at the Teaching Hospital. The number of carotid artery injuries was relatively low and accounted for a small percentage of patients. Most often, interventions were undertaken outside the Teaching Hospital, in various hospitals and surgical departments cooperating with the Teaching Hospital, where the vascular surgeon on duty was usually summoned. In several cases, the distance to hospitals calling for help was 60–80 km or even as far as 140 km. The time from injury to the start of remedial surgery ranged from 30 minutes to 10 hours, and it represented the biggest problem for the vascular surgery team. The evaluated group included 42 male and 31 female patients,
The patients were divided according to their primary condition into three groups (Tab. II.). The number of patients with iatrogenic injuries totalled 44 (61%). A temporary suction drain was placed in the dissected arterial segments, and only at this point was an appropriate method of injury often determined the possibility and nature of the injury.

In this group of patients that end-to-end anastomosis (6 patients) and vascular suture (6 patients) was only rarely possible to perform. It was often necessary to resect the vessel along with the tumour. In 18 cases, it was necessary to perform plastic surgery and insertion of the harvested saphenous vein, and in two cases, a PTFE graft. In 12 cases of proximal CIA injury, end-to-end anastomosis was not possible. The vessel wall was significantly altered by the tumour, and no suitable autologous graft material could be found. In these patients, reconstruction was performed by anastomosing the ECA to the distal ICA.

In the first three age groups (18–60 years), carotid artery lesions were found in similar numbers (Fig. 2.), also the gender distribution appeared to be not significant (Fig. 3.). When analysing the numbers of injuries by year, it was found that for carotid artery injuries, the incidence was constant, but the number of iatrogenic injuries increased significantly over time. All reconstructive procedures in iatrogenic trauma cases were carried out after administration of unfractionated heparin (UFH) anticoagulation. The mechanism of injury often determines the possibility and nature of the injury to the artery. It may be crushed, closed by a thrombus, partially or fully ruptured. In neck tumours, the vessels may be pathologically altered due to infiltration. The character of the injury determines the treatment, but in all cases, the procedure should be carried out by a vascular surgeon.

Tab. I. Classification by type of injury.

<table>
<thead>
<tr>
<th>TYPE OF INJURY</th>
<th>NUMBER/PERCENTAGE</th>
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<tbody>
<tr>
<td>Number/percentage</td>
<td>29 (39%)</td>
</tr>
<tr>
<td>Iatrogenic injuries</td>
<td>44 (61%)</td>
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<td>Total</td>
<td>73 cases</td>
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Tab. II. Classification of patients with iatrogenic carotid artery injuries by the primary condition.

<table>
<thead>
<tr>
<th>REASON FOR PRIMARY TREATMENT</th>
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<tbody>
<tr>
<td>Recurrent goitre</td>
<td>6 (14%)</td>
</tr>
<tr>
<td>Glomus tumour</td>
<td>9 (20%)</td>
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<tr>
<td>Other tumours</td>
<td>29 (66%)</td>
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<td>Total</td>
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Tab. III. Types of surgical procedures performed for iatrogenic injuries.

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<th>TYPE OF MANAGEMENT</th>
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<td>Vascular suture without/with patch</td>
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<td>End-to-end anastomosis</td>
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<td>Plastic surgery using a vein or PTFE prosthesis implant</td>
<td>20 (18+2) (45%)</td>
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<td>End-to-end anastomosis of ECA with z ICA</td>
<td>12 (27%)</td>
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Tab. IV. Complications in the iatrogenic injury group.

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<td>Cerebral stroke</td>
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<td>2 (18%)</td>
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The group has a predominance of cases in the 5th and 6th decades of life, usually associated with an increased incidence of oncological conditions in this age group. Men constituted 70% of patients. In all cases, patients with iatrogenic arterial injuries were operated on in different departments and hospitals. The procedures were carried out under general anaesthesia, and carotid artery injuries usually occurred during the first phase of the surgery.

The risk of iatrogenic vascular injury increases significantly when the infiltrated vessel wall is weak and easily damaged. Iatrogenic injuries are therefore possible even with a clear surgical field view.

Neurological complications occurred in 11 patients (25%) (Tab. III.). Two patients in a coma died within 48 or 72 hours after the procedure. Major neurological disorders of stroke with hemiparesis, occurred in 3 patients, and another 6 patients developed transient neurological deficit (TND) symptoms. Although the period of cerebral ischaemia lasted up to 8 hours, the neurological symptoms entirely disappeared. Five patients were diagnosed with wound healing disorders. Follow-up examinations, including ultrasound, revealed no stenosis or obstruction of the reconstructed vessels.

The number of patients with iatrogenic injuries totalled 44 (61%). The patients were divided according to their primary condition into three groups (Tab. II.).

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RESULTS AND COMPLICATIONS

A team from the Teaching Hospital was called in for the repair procedure for consultation by phone. The surgery was essentially schematic and similar to management of injuries in any trauma case: stop bleeding, therapeutic anticoagulation with UFH (5000 I.U.) and if possible, secure cerebral perfusion by inserting a flow tube (this turned out to be unrealistic). During the phone call, there were recommendations provided that could be fulfilled by the operating team: control the bleeding by placing vascular clamps, if available, or inserting forceps gently. The recommendation of local pressure (loco laesionis) proved to be the most beneficial. The type of reconstruction depended on the location and size of the injury and any arterial defect resulting from tumour resection. The procedures performed were shown in Tab. III.

In this group of patients that end-to-end anastomosis (6 patients) and vascular suture (6 patients) was only rarely possible to perform. It was often necessary to resect the vessel along with the tumour. In 18 cases, it was necessary to perform plastic surgery and insertion of the harvested saphenous vein, and in two cases, a PTFE graft. In 12 cases of proximal CIA injury, end-to-end anastomosis was not possible. The vessel wall was significantly altered by the tumour, and no suitable autologous graft material could be found. In these patients, reconstruction was performed by anastomosing the ECA to the distal ICA.

CONCLUSIONS

Iatrogenic carotid artery injuries represent a vascular surgery emergency with a high gravity due to the high mortality rate. Diagnosis and therapy are subject to severe time constraints. The mechanism of injury often determines the possibility and nature of the injury to the artery. It may be crushed, closed by a thrombus, partially or fully ruptured. In neck tumours, the vessels may be pathologically altered due to infiltration. The character of the injury determines the treatment, but in all cases, the procedure should be carried out by a vascular surgeon.
The results obtained allow the following conclusions to be drawn:

1. Iatrogenic carotid artery injuries are subject to a high mortality rate and are often accompanied by severe neurological consequences;
2. Significantly better treatment results are obtained in iatrogenic arterial injuries. This is mainly due to easier and quicker diagnosis and shorter time of restoring cerebral circulation;
3. Surgery for neck tumours carries a significant risk of internal carotid artery injury. It is beneficial to perform these procedures in a multidisciplinary team with the participation of a vascular surgeon. In cases where it has been damaged, the use of a suction drain on the one hand, protects the blood supply to the brain, and on the other hand, allows a quiet choice of the reconstruction method;
4. If the proximal part of the internal carotid artery is damaged, the fastest reconstruction method is external carotid artery anastomosis;
5. An interesting alternative in cases of infected wounds and lack of autologous material (patient’s vein, inability to use the external carotid artery) is the insertion of a pericardial patch.

REFERENCES

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The authors declare that they have no competing interests.

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Cite this article as: Wolf B., Czajkowska M., Dorobisz A.: Intraoperative Carotid Artery Injuries. Review of the literature, analysis of the material of one centre; Pol Przegl Chir 2021; 93: (1–6); DOI: 10.5604/01.3001.0015.6102 (Advanced online publication)