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Original article

Incidence of brachial plexus injury after cardiac surgery: a retrospective study

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Abstract

Background: **Brachial plexopathy is a rare but debilitating injury associated with cardiac surgery. The reported incidence varies widely. Several risk factors have been described, including both patient and surgical factors.**
Objectives: **The aim of this study is to (1) investigate the incidence of brachial plexus injury in cardiac surgery in a three-year period in our hospital, (2) give an overview of risk factors and possible mechanisms of brachial plexopathy, and (3) consider the legal ramifications of these injuries.**
Design and setting: **single centre retrospective study**
Methods: **Data were collected retrospectively from all patients undergoing cardiac surgery in a major hospital in a three-year year period (N = 1305). Hospital records were screened for patients who underwent an electromyography after their surgery. Those cases were further investigated for brachial plexus injury. Patient characteristics and data applying to known risk factors for peroperative nerve injury were obtained.**
Results: **Brachial plexus injury was observed in 7 out of 1305 patients (0.54%). All patients with brachial plexus injury underwent coronary artery bypass surgery with internal mammary artery harvesting at the side of the injury. No further analysis concerning risk factors was performed since only seven cases were identified and underreporting was suspected.**
Conclusion: **Our data suggest that brachial plexus injury in cardiac surgery might be associated with asymmetrical sternal retraction during internal mammary artery harvesting. These findings correspond with previous reports, although it would be interesting to further investigate the importance of the exact placement and type of retractor used.**

Keywords: **brachial plexopathy, peripheral nerve injury, cardiac surgery, median sternotomy, malpractice.**

Introduction

Brachial plexopathy is a recognized complication of cardiac surgery, in particular coronary artery bypass grafting (CABG)[1, 2]. The reported incidence of brachial plexus injury in cardiac surgery varies widely, with numbers ranging from 0.5% to 12%[3-10]. Nerve injury can be the result of stretch, direct trauma or compression, to which the brachial plexus is notably susceptible[11]. It is formed by the anterior rami of C5 – T1, which pass between the anterior and middle scalene muscles, combining into the superior, middle and inferior trunks. These trunks pass laterally over the first rib and enter the axilla, then split and recombine into divisions and cords respectively, ultimately giving rise to the various terminal nerves of the upper limb[12] (Fig. 1).

The brachial plexus is prone to stretch injury since it is fixed by fascia both at the transverse processus and in the axilla. Therefore any increase in distance between these points can result in stretch injury to the nerve bundles[11]. A cadaver study by

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This study was approved by the clinical trials unit of Ziekenhuis Oost-Limburg, Genk, Belgium (CTU 2021035, chairman Mr. Tom Arts, 01/05/2021). Informed consent was not obtained because of the retrospective nature of the study and the use of anonymous clinical data. Clinical registration number: N/A.

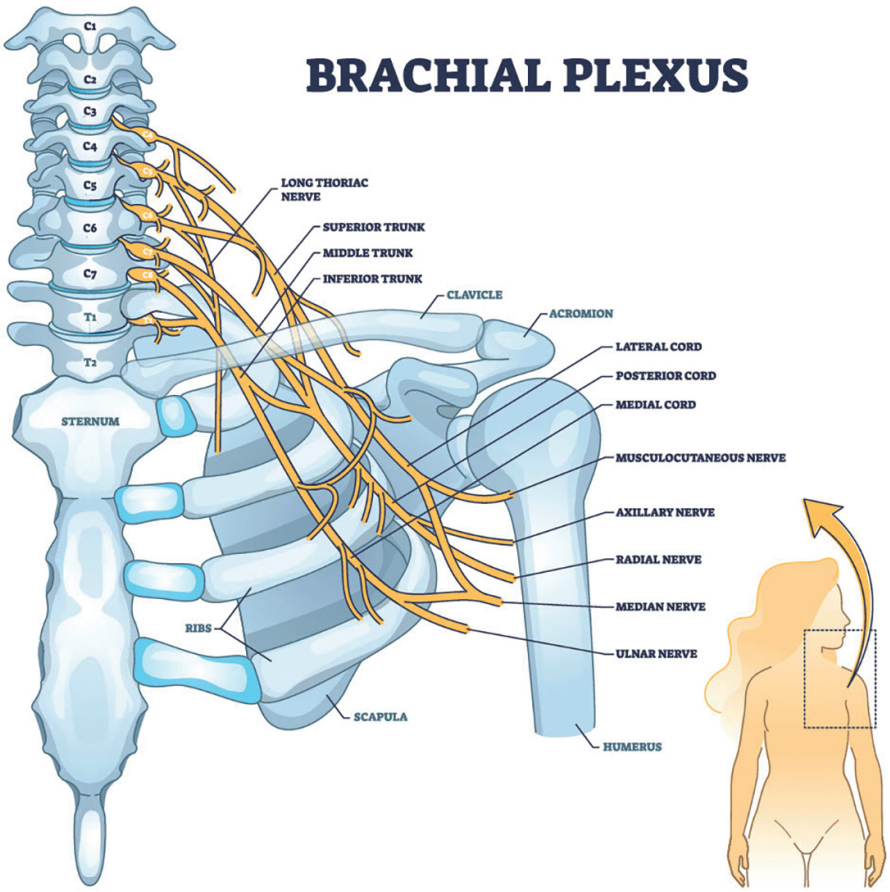

Fig. 1 — Brachial plexus (from iStock.com/VectorMine).

Kirsh et al.[13], for example, showed displacement of the clavicles into the retroclavicular space and superior rotation of the first ribs during sternal retraction, causing abnormal tension on the brachial plexus. Furthermore, the narrow space between the first rib and the clavicle makes the plexus prone to compression if the first rib is displaced or broken. Finally, the brachial plexus is vulnerable to direct damage because of its superficial location[1, 2].

The prognosis of perioperative nerve injury depends on the severity of the injury. The duration of the conduction block can vary from minutes in the case of mild compression to weeks or months in the case of demyelination or axonal loss respectively. In rare cases, the damage is so severe that regrowth is nearly impossible, regrettably leading to permanent loss of function[14].

Brachial plexus injury is the most common peripheral nerve injury after cardiac surgery, and is more prevalent in cardiac surgery compared to non-cardiac surgery. Although often transient in nature, it can lead to serious patient disability and malpractice claims[15].

The aim of this study is to (1) investigate the incidence of brachial plexus injury in cardiac surgery in a three-year period in our hospital, (2) give an overview of risk factors and possible mechanisms of brachial plexopathy, and (3) consider the legal ramifications of these injuries.

Patients and methods

This study was approved by the clinical trials unit of Ziekenhuis Oost-Limburg, Genk, Belgium (CTU 2021035, chairman Mr. Tom Arts, 01/05/2021). Because of the retrospective nature of the study and the use of anonymous clinical data, ethical commission approval was not sought prior to the start of the study; this decision was later agreed upon by our hospital's ethical commission (chairman Dr. Patrick Noyens, 26/04/2023). No explicit statement on the need for informed consent was made. STROBE guidelines[16] were used while writing the article.

In this retrospective study, data were collected from all patients in a major hospital who underwent cardiac surgery in a three-year period (2018-2020). This includes valve surgery (encompassing the different types of valve plasty and replacement as well as minimal access aortic valve replacement (mini-AVR) and robot-assisted mitral valve plasty), CABG, off-pump coronary bypass graft (OPCAB), robot-assisted minimally invasive direct coronary bypass graft (MIDCAB), type A dissection repairs and Bentall procedures. The records were

automatically screened for patients who came in for an electromyography (EMG). The resulting cases were manually screened for brachial plexus injury. Patient characteristics and data applying to known risk factors for peroperative nerve injury were obtained. The data consequently only include patients with EMG-confirmed nerve injury.

All patients were positioned supine with their arms padded and fixed alongside the body, palms facing down. Additionally in robot-assisted procedures, a pad was placed under one shoulder (left for MIDCAB procedures, right for Heartport procedures) and the operating table was tilted to the opposite side to facilitate access. Internal jugular vein cannulation was generally performed at the right side unless contraindicated. This procedure was performed either by anatomical landmarks or ultrasound-guided, depending on the anesthetist's preference and expected difficulty of the procedure. Swan-Ganz catheterization was performed in select cases e.g. combined procedures or poor preoperative cardiac status. Myocardial protection during cardiopulmonary bypass (CPB) was routinely achieved by warm blood cardioplegia, and normothermia was maintained unless surgical conditions mandated hypothermia.

Two different types of sternal and asymmetrical retractor were used, dependent on the preference of the surgeon. For sternal retraction, either the Kuyper-Murphy (Teleflex Inc, Wayne, PA) or the Favaloro-Morse (Teleflex Inc, Wayne, PA) retractor was used. For asymmetrical retraction during internal mammary artery harvesting, either the Bugge (Teleflex Inc, Wayne, PA) or the Chevalier-Delacroix (Chevalier-Delacroix, Paris, France) retractor was used.

Results

Brachial plexus injury was observed in 7 out of 1305 patients (0.54%). Overall data is shown in Table I. The seven patients with brachial plexus injury will also be described case by case.

We found that all patients with brachial plexopathy underwent coronary artery bypass surgery, compared to 66% (52% CABG only, 14% CABG combined with valve or other surgery) in the control group. In most CABG patients, arterial conduits were used; harvesting of only the great saphenous vein was done in only 3% of the total patient cohort. Of the seven cases with brachial plexus injury, five patients (71%) underwent bilateral internal mammary artery harvesting, the other two patients (29%) underwent both left internal mammary artery and great saphenous vein harvesting. In the control group, 45% underwent BIMA harvesting, 35% LIMA + GSV and 15% LIMA only harvesting. All seven cases were male patients, compared to 74% in the control group. The mean EuroSCORE II (European System for Cardiac Operative Risk Evaluation, predicts risk of in-hospital mortality after major cardiac surgery) was lower in the group with brachial plexopathy than in the control group, 0.99% vs 3.88% respectively. No statistical analysis concerning risk factors was performed since only seven cases were identified and underreporting was suspected.

Case 1:

A 58-year old man without significant history underwent a semi-urgent CABG (4 bypasses) with left internal mammary artery (LIMA) and right internal mammary artery (RIMA) harvesting for unstable angina. Postoperative checkup revealed hypoesthesia and paresthesia in the entire left ulnar nerve distribution area. The patient also had mild weakness in his left hand. An EMG study, carried out seven months after the initial injury, confirmed chronic inferior trunk damage with axonal degeneration at the left brachial plexus (mainly C8). The patient was referred for physical therapy. The prognosis for this patient was poor, with persistent neurological symptoms.

Case 2:

A 40-year old man with a history of arterial hypertension and obesity underwent a CABG (3 bypasses) with LIMA and RIMA harvesting for coronary artery disease. He presented with a mild paresis of the left upper limb postoperatively (4+/5 proximally and 4/5 distally). No sensory disturbances were reported. EMG showed slight deviations compatible with left-sided inferior trunk plexopathy. Motor function was already markedly improved several hours after extubation. He received physical therapy during one week, after which good recovery was observed.

Case 3:

A 58-year old male with a history of arterial hypertension underwent a semi-urgent OPCAB (4 bypasses) with LIMA and RIMA harvesting. Postoperatively, he suffered from pain and loss of function in the left arm. EMG 3.5 months postoperatively confirmed left inferior trunk plexopathy, without clinical motor deficit at this time. No further neurological follow-up was documented.

Case 4:

A 57-year old man with a history of arterial hypertension and peripheral artery disease underwent an OPCAB (3 bypasses) with LIMA and RIMA harvesting for coronary artery disease. Postoperatively, he had pain inferoposterior in the

Table I. — Overview of patient characteristics and surgical factors. Data were analyzed using SPSS 28. BIMA, bilateral internal mammary artery; BMI, body mass index; CABG, coronary artery bypass graft; CPB, cardiopulmonary bypass; CVA, cerebrovascular accident; GSV, great saphenous vein; LIMA, left internal mammary artery; RIMA, right internal mammary artery; TIA, transient ischemic attack.

	Control group (N=1298)	Brachial plexus injury (N=7)
Male	963 (74.2%)	7 (100%)
Female	335 (25.8%)	0
BMI (mean)	27.5	27.3
Previous cardiac surgery	33 (2.5%)	0
Smoking		
Non-smoker	758 (58.4%)	4 (57%)
Current smoker	201 (15.5%)	3 (43%)
Ex-smoker	339 (26.1%)	0
Diabetes	283 (21.8%)	2 (28.6%)
Arterial hypertension	782 (60.2%)	5 (71.4%)
Peripheral vascular disease	92 (7.1%)[a]	1 (14.3%)
History of TIA/CVA	75 (5.8%)[b]	1 (14.3%)
Urgency		
Elective	950 (73.2%)	5 (71.4%)
Urgent	262 (20.2%)	2 (28.6%)
Emergency	76 (5.9%)	
Type of surgery		
CABG	679 (52.3%)	7 (100%)
Valve	324 (25%)	
CABG + valve	153 (11.8%)	
CABG + other	13 (1%)	
Valve + other	42 (3.2%)	
CABG + valve + other	15 (1.2%)	
Other	62 (4.8%)	
Conduits used (CABG)		
Total	830	7
LIMA only	129 (15.5%)	0
RIMA only	3 (0.4%)	0
GSV only	25 (3%)	0
BIMA	373 (45%)	5 (71.4%)
LIMA + GSV	290 (35%)	2 (28.6%)
RIMA + GSV	10 (1.2%)	0
Cardiopulmonary bypass (CPB)	927 (71.4%)	4 (57.1%)
Blood cardioplegia	572 (61.7%)[c]	4 (100%)
Crystalloid cardioplegia	67 (7.2%)[c]	0
EuroSCORE II (mean)	3.88%	0.99%

[a]no data in 457 cases (35.2%); [b]no data in 322 cases (24.8%); [c]no data in 288 cases (31%).

right axilla, radiating to digit 4 and 5, as well as mild paresis. EMG confirmed right-sided inferior trunk plexopathy. MRI excluded cervical radiculopathy. A repeat EMG study after two months showed unchanged motor axonal degeneration in myotomes C8-T1. The patient received physiotherapy. No further neurological follow-up was scheduled.

Case 5:

A 73-year old man with a history of type 2 diabetes, arterial hypertension, atrial fibrillation, obesity and coronary artery stenting underwent a CABG with LIMA and great saphenous vein (GSV) harvesting for coronary artery disease, combined with ablation (pulmonary vein isolation) for atrial fibrillation. He presented postoperatively with hypoesthesia at the medial side of the left lower arm and digit 4-5. No motor deficits were observed. An EMG study was performed approximately three months after the surgery, at which time some recuperation of sensory function had occurred. The EMG confirmed chronic left lower brachial plexopathy with signs of ongoing

reinnervation. No further neurological follow-up was documented.

Case 6:

A 77-year old male with an extensive medical history, including type 2 diabetes, arterial hypertension, rheumatoid arthritis and a transient ischemic attack, underwent a CABG (4 bypasses) with LIMA and GSV harvesting for coronary artery disease. Postoperatively, he complained of pain in the left shoulder. After a couple of days this pain started radiating to the arm and hand, blisters were observed and left-hand weakness was described. The patient was started on acyclovir for herpes zoster in the left C6 dermatome, and pregabaline for neuropathic pain. However, after an EMG-study four months later, the persistent complaints were attributed to post-sternotomy brachial plexopathy at the level of the inferior trunk. The pain had not resolved at that time.

Case 7:

A 62-year old man with a history of arterial hypertension and inferior myocardial infarction with cardiac stenting underwent an OPCAB (4 bypasses) with LIMA and RIMA harvesting for coronary artery disease. Postoperatively, sensory disturbances in the right hand (digit 4-5) and lower arm, as well as weakness in the right hand were observed. EMG confirmed the diagnosis of right inferior trunk brachial plexopathy, with a fairly good prognosis. Physiotherapy was started. Later on, pregabaline was started for neuropathic pain. The symptoms improved over the next months. At the last checkup, 1.5 years after the surgery, only minimal paresthesia in digit 4-5 was present.

Discussion

The first aim of this study was to investigate the incidence of brachial plexus injury after cardiac surgery in our hospital. We found an incidence of 0.54%, corresponding with the lowest rates found in the literature. However, some of the patients we identified only underwent further neurological examination and an EMG study several months after the surgery, indicating that mainly patients with persistent complaints were referred. Furthermore, the presence of neurological deficits was not always mentioned in the patient files until the time of referral. This suggests that our study mainly identified the more severe cases. Since most brachial nerve injuries are transient in nature, the incidence observed in this study is probably an underestimation. In order to address the underreporting of perioperative nerve injuries, a standardized questionnaire has now been included in the follow-up consultations of our cardiac surgeons.

It is remarkable that all patients with brachial plexus injury underwent coronary artery surgery (CABG or OPCAB) with left internal mammary artery (LIMA) grafting in all seven cases and right internal mammary artery (RIMA) grafting in 5 out of 7 cases. The two patients with right sided brachial plexopathy are among those who underwent RIMA harvesting. Both sternal retraction during median sternotomy and asymmetrical sternal retraction during internal mammary artery (IMA) harvesting have been proposed as important factors in the development of brachial plexus injury[2]. Moreover, a study by Jellish et al.[17] showed that the exact type of retractor used might be relevant: the use of the Delacroix-Chevalier asymmetrical retractor was associated with less neurophysiologic dysfunction compared to the Pittman and Rultract asymmetrical retractors, although no difference in clinical outcomes was observed. In our study, the use of an asymmetrical sternal retractor seems to be the key factor, as none of the patients who underwent a median sternotomy without asymmetrical retraction (n = 428) were identified with brachial plexus injury.

Other associated factors for perioperative nerve injury are patient positioning, jugular vein cannulation, hypothermia, hypotension and patient factors such as age, hypertension, diabetes mellitus, smoking, extremes of weight, peripheral artery disease and preexisting neuropathy[1,2].

Several studies have been conducted on patient positioning. It has been suggested that a hands-up position (arms abducted < 90° and elbows flexed and 20 cm above the level of the table) might be beneficial compared to an arms at side position. The results are inconclusive, although the arms at side position might be associated with a higher incidence of ulnar neuropathy[18]. In our hospital, all patients were positioned with the arms at the side.

Jugular vein cannulation might pose some risk due to its close proximity to the brachial plexus, which makes it prone to direct needle trauma or compression by hematoma formation. However, no direct correlation has been shown with brachial plexus injury[2].

The importance of patient factors such as hypertension, diabetes, smoking and preexisting neuropathy might have to do with the double crush syndrome. This syndrome refers to the synergistic effects of two or more subclinical nerve insults along one nerve, which results in symptomatic (and possibly permanent) nerve damage. Hypertension, smoking and diabetes can all lead to microvascular

changes contributing to (subclinical) peripheral neuropathy, thus making the nerves more vulnerable to perioperative injury[15,19].

Another noteworthy observation is that all brachial plexus injuries in this study occurred in the inferior trunk. This corresponds with an earlier study by Ben-David et al.[14] which showed a predominance of sensory complaints in the lower roots in patients who underwent median sternotomy, in contrast to non-cardiac surgery after which motor deficits in the upper and middle roots were more evident. This difference also substantiates the use of sternal retractors as an important causative factor of brachial plexus injury in cardiac surgery, as sternal retraction has been shown to cause displacement of the clavicles into the retroclavicular space and superior rotation of the first rib, thereby stretching the inferior brachial plexus[13].

Although often transient in nature, nerve injury can lead to serious patient disability and malpractice claims. A review of the Anesthesia Closed Claims Project database showed that 12% of malpractice claims involve peripheral nerve injuries, of which 36% pertain to the brachial plexus. The etiology is usually multifactorial, making it difficult to prevent injuries despite adequate care[15].

Positioning a patient on the operating table is characterized by a reasonable efforts obligation. The surgeon and anesthesiologist make the upmost efforts to minimize damage from patient positioning by using cushions, pads and visual inspection of limbs and neck. Despite all these preventive measures, brachial nerve injuries following cardiac surgery remain possible. Generally, certain patient positions are necessary in order to make that specific type of surgery feasible (e.g. minimal invasive robotic cardiac surgery). In a legal procedure the surgeon and anesthesiologist will be compared with the abstract concept of normally careful colleagues. The involved physicians are without any error and blame when normally careful colleagues could encounter similar nerve damages in a similar cardiac surgery patient.

In conclusion, brachial plexus injury is a rare but debilitating complication of cardiac surgery. A retrospective study in 1305 patients in our hospital showed an incidence of 0.54% of EMG-confirmed cases. No further analysis concerning risk factors was performed since only seven cases were identified and underreporting was suspected. However, it is noteworthy that all patients with brachial plexus injury underwent coronary artery bypass surgery with internal mammary harvesting at the side of the injury. This corresponds to previous findings suggesting that asymmetrical retraction during IMA harvesting might lead to the development of brachial plexus injury in cardiac surgery. Therefore, attention should be paid to the amount and duration of (asymmetrical) sternal retraction as well as the placement of these retractors. In addition, it would be interesting to further investigate the impact of different types of retractors.

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Herbert Gutermann: Data Curation; Writing - review & editing.
Tom Fret: Conceptualization; Methodology; Project Administration; Resources; Supervision; Writing – original draft; Writing - review & editing.

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