

Comparison of coronary artery bypass grafting using the MIDCAB, OPCAB and CABG methods performed in patients with diabetes and hypertension: Case reports

Porównanie zabiegów pomostowania aortalno-wieńcowego metodą CABG, OPCAB i MIDCAB wykonanych u pacjentów z cukrzycą i nadciśnieniem tętniczym – opisy przypadków

Sabina Dyszy^{1,A,B,D,F}, Martyna Kluszczyńska^{2,C,D,F}

¹Chair and Department of Psychology, Medical University of Silesia in Katowice, Katowice, Poland

²Department of Gerontology and Geriatric Nursing, Leszek Giec Upper-Silesian Medical Centre, Medical University of Silesia in Katowice, Katowice, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Pielęgniarstwo i Zdrowie Publiczne, ISSN 2082-9876 (print), ISSN 2451-1870 (online)

Piel Zdr Publ. 2020;10(3):189–195

Address for correspondence

Sabina Dyszy

E-mail: sabina-dyszy@wp.pl

Funding sources

None declared

Conflict of interest

None declared

Received on September 6, 2019

Reviewed on October 8, 2019

Accepted on February 10, 2020

This is a translated article.

Please cite the original

Polish-language version as

Dyszy S, Kluszczyńska M. Porównanie zabiegów pomostowania aortalno-wieńcowego metodą CABG, OPCAB i MIDCAB wykonanych u pacjentów z cukrzycą i nadciśnieniem tętniczym – opisy przypadków.

Piel Zdr Publ. 2020;10(3):189–195. doi:10.17219/pzp/118084

DOI

10.17219/pzp/118084

Copyright

© 2020 by Wrocław Medical University

This is an article distributed under the terms of the

Creative Commons Attribution 3.0 Unported License

(<https://creativecommons.org/licenses/by/3.0/>)

Abstract

Cardiovascular diseases are the most common cause of death not only in Poland, but also in most European countries. Increasingly, myocardial ischemia, hypertension and diabetes are becoming the leading conditions the patients suffer from. One of the methods of coronary artery recanalization is angioplasty performed during coronary angiography. The procedure involves inserting a catheter ended with a balloon that widens the vessel. If the patient's anatomical conditions are severe or vasoconstriction prevents catheter passage, the patient is eligible for coronary artery bypass surgery. Coronary artery bypass surgery is currently the most frequently performed surgical procedure in the world, with more than half of the indications for it being coronary heart disease. The development of medicine has allowed to perform surgery with or without the use of extracorporeal circulation and without opening the chest – with access through minithoracotomy. All methods used are properly selected and adjusted to the patient's general condition, the surgeon's skills and access to modern equipment. The main objective of this paper was to analyze 3 coronary artery bypass grafting methods on the basis of case reports, and to compare them with other literature sources.

Key words: coronary artery disease, hypertension, CABG, MIDCAB, OPCAB

Streszczenie

Choroby układu krążenia są najczęstszą przyczyną zgonów nie tylko w Polsce, ale również w większości krajów europejskich. Niedokrwienie mięśnia sercowego oraz nadciśnienie tętnicze i cukrzyca stają się wiodącymi schorzeniami, na które cierpią pacjenci. Jedną z metod udrażniania naczyń wieńcowych jest angioplastyka wykonywana podczas koronarografii. Zabieg polega na wprowadzeniu cewnika zakończonego balonikiem, który poszerza naczynie. Jeśli występują ciężkie warunki anatomiczne chorego lub zwężenie naczyń uniemożliwia przejście cewnika, chory kwalifikowany jest do operacji pomostowania aortalno-wieńcowego. Jest to aktualnie najczęściej wykonywana procedura operacyjna na świecie, do której ponad połowę wskazań stanowi choroba wieńcowa. Rozwój medycyny pozwolił na wykonywanie operacji z użyciem lub bez użycia krążenia pozaustrojowego oraz z dostępu przez minitorakotomię – bez konieczności otwierania klatki piersiowej. Wszystkie metody są odpowiednio dobierane i dostosowywane do stanu pacjenta, umiejętności chirurga oraz dostępu do nowoczesnego sprzętu. Celem niniejszej pracy była analiza 3 metod pomostowania aortalno-wieńcowego na podstawie opisów przypadków oraz porównanie ich z innymi doniesieniami z literatury.

Słowa kluczowe: choroba wieńcowa, nadciśnienie, CABG, MIDCAB, OPCAB

Introduction

Cardiosurgery is a narrow field of medicine which dates back to the end of the 19th century. In September 1896, a German surgeon, Ludwig Rehn, performed a successful surgery for a cardiac stab wound. In Poland, the first surgical treatment of a similar cardiac trauma was carried out by Witold Horodyński on December 6, 1898, but unfortunately, it ended in the patient's death.¹ The isolation of heparin from a dog's liver in 1916 was fundamental to the development of cardiac surgery.^{2,3} This discovery facilitated the control of the blood clotting process. Another significant event was the introduction of a roller/peristaltic pump by DeBakey (used in cardiopulmonary bypass – CPB) in 1943, which takes over the role of the heart in extracorporeal circulation. The first surgeon to perform open heart surgery using the CPB technique was Gibbon, who in 1953 effectively filled the atrial septal defect using the DeBakey device during surgery. Since then, cardiac surgery has advanced enormously.⁴

The development of the surgical treatment of coronary artery disease has significantly improved early and distant results. This was possible by minimizing the invasiveness of coronary artery surgery. In the classical method, i.e., coronary artery bypass grafting (CABG), the use of CPB provides good surgical conditions; however, it is associated with many complications, such as strokes, deterioration of the renal function, respiratory failure, and myocardial ischemia. This method requires the cannulation of the myocardium and the aorta as well as the clamping of the ascending aorta, which may cause the release of embolic material. The application of CPB significantly disrupts the maintenance of blood–brain barrier (BBB) and can lead to early neurological complications. Selected studies and records of early results in patients operated with the use of the CPB technique show that the incidence of strokes or transient ischemic attacks varies between 1% and 3%. To reduce the complications, the techniques of off-pump coronary artery bypass grafting (OPCAB) are increasingly used on a beating heart. The

OPCAB surgery is technically demanding, not only because of a 'mobile' operating field, but also because of difficult hemodynamic conditions during surgery, such as the luxation of the heart and coronary occlusion during anastomosis.⁵

The main objective of this paper was to analyze 3 CABG methods on the basis of case reports, and to compare them with other literature sources.

Material and methods

In order to conduct the research, access to the medical records of patients hospitalized in the cardiac surgery department was gained. Medical records kept in the operating suite by the anesthesiologist and the perfusionist, descriptions of the course of operations as well as documents filled in after surgery at the intensive care unit and cardiac surgery department were analyzed.

Coronary artery bypass surgery methods

The CABG surgery is a cardiac surgery involving the implantation of a bypass from the aorta to the coronary artery behind the site of stenosis. In 1953, the CPB and hypothermia methods were introduced, whereas cardioplegia was implemented in the 1960s. It was a major advance in cardiac surgery. The first coronary artery bypass surgery (1967) facilitated the development of those procedures, which have constituted 80% of cardiac surgeries in the 21st century. Cardiopulmonary bypass provided the cardiac surgeon with the comfort of operating an immobile heart, at the same time contributing to the possibility of complications such as renal failure, ischemic myocardial damage or central nervous system damage. Cardioplegia is the stopping of the heart muscle activity during diastole using a potassium-rich solution. Its essence was the intracoronary or retrograde – through the cardiac

veins – introduction of a solution containing supraphysiological potassium concentrations. This type of heart protection during a cardiac surgery was implemented in 1955. At the beginning of the 21st century, the cardioplegic solutions differed in composition, some contained the patient's diluted blood with an increased concentration of potassium. In Poland, the first successful attempts to construct a heart replacement device were made by Jan Krotoski of Poznań in 1954. At the beginning of the 21st century, the set for CBP comprised an oxygenator (oxygenating the blood), a pump – usually a roller pump (replacing the heart), a heat exchanger (cooling or heating the blood depending on the procedure time), and a system of filters and cannulas.⁶

The material used to create anastomosis are usually the saphenous veins taken from the shanks. The radial arteries, the right internal mammary artery (RIMA) and the left internal mammary artery (LIMA) as well as artificial vascular prostheses can also be used. Creating artificial connections between the main artery (the aorta) and the coronary arteries bypassing the stenosis sites allows to improve blood supply to the ischemic region of the myocardium. The procedure is performed under general anesthesia and with the use of CBP. It is necessary to open the chest to gain access to the heart. During the classic procedure, the chest is opened by making an incision in the sternum. In recent years, many new methods of surgery have emerged, which are less invasive.⁷

Thanks to the stability of the operating field, the bypass graft surgery performed on a stopped heart facilitates the extremely precise implantation of the previously collected arterial and venous vessels between the site of the lesion and the patient's aorta, regardless of the extent of the lesions and their location (Fig. 1). Cardiopulmonary bypass ensures optimal organ perfusion throughout the entire procedure, enabling comprehensive reconstruction and CABG. It has been proven that the use of CPB is associated with strong activation of the coagulation and fibrinolytic systems, which may cause serious thrombotic and hemorrhagic complications. Moreover, CPB damages the morphotic elements of blood, impairing their functions and contributing to the systemic inflammatory response syndrome (SIRS).⁸

The prevalence of coronary artery disease and indications for myocardial revascularization procedures have led to the development of methods which, while maintaining precision, have made it possible to avoid or reduce the adverse effects of CBP. One of such methods is OPCAB, which requires more technical skills from the cardiac surgeon as well as cardiac stabilization devices. Device such as Octopus immobilizes the field of the implanted bypass by means of sleeves that are attached to the heart with the use of a suction device connected to a vacuum.⁶

The OPCAB technique is most commonly used in patients at high risk of surgical complications resulting from

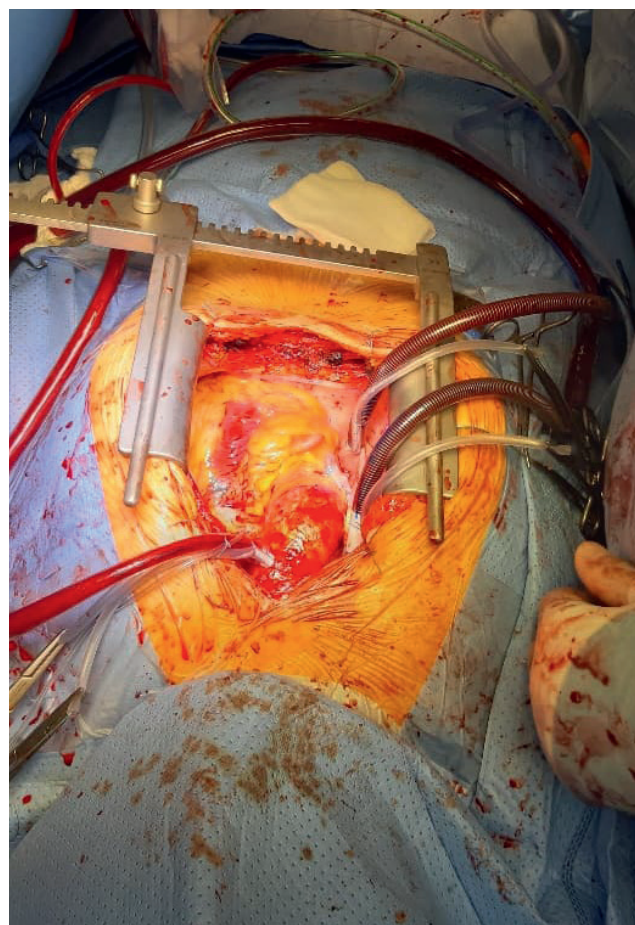


Fig. 1. Coronary aortic bypass grafting using the CABG technique

Ryc. 1. Pomostowanie aortalne wieńcowe techniką CABG

cardiac arrest and the use of CBP (Fig. 2). This method is usually used in patients with disseminated atherosclerosis (including the aorta and the carotid arteries), poor left ventricular function, renal failure, and concomitant cancer (or a history of cancer) – CBP could contribute to the spread of disease in such patients. Both CABG and OPCAB require median sternotomy, thus, over the past few years, other methods were developed to minimize the size of the incision. This shortens the recovery period after surgery and reduces the risk of complications associated with sternum instability (especially in obese people, diabetics or patients with a history of pulmonary diseases). A better cosmetic effect is achieved as well.⁹

Minimally invasive coronary procedures, such as the minimally invasive direct coronary artery bypass (MID-CAB), are technically more difficult and demanding as compared to the other methods, but they are characterized by high effectiveness and safety of revascularization with a minimal chest trauma (Fig. 3).^{10,11} This is a procedure performed without CBP. Due to a limited and small operating field (8–10 cm), the procedure is performed in patients with the stenosis of 1 or 2 coronary vessels – the

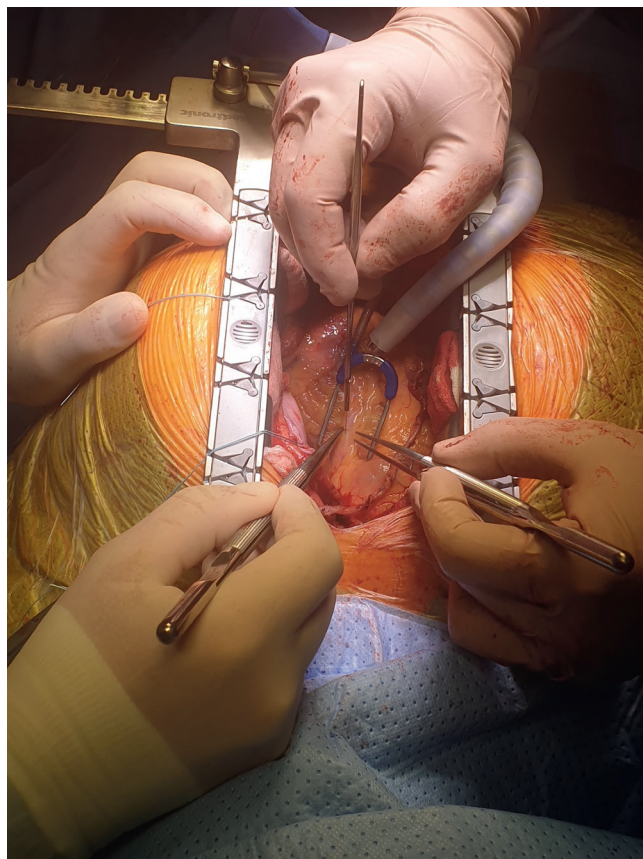


Fig. 2. Coronary aortic bypass grafting using the OPCAB technique

Ryc. 2. Pomostowanie aortalne wieńcowe techniką OPCAB

anterior interventricular branch of the left coronary artery (i.e., left anterior descending – LAD) and the first diagonal artery (D1). According to studies, the implantation of LIMA into LAD is the best choice for treating this artery. The surgical method described above is associated with high patency of bypasses, which is more than 90% in a ten-year observation.^{12,13} The results of prospective randomized studies comparing percutaneous coronary intervention (PCI) combined with bare metal stent implantation to the implantation of LIMA into the proximal segment of LAD confirm the definite advantage of the surgical procedure.¹¹

Case reports

Patient considered eligible for CABG

First patient: A 67-year-old obese male admitted to hospital due to chest pain of compression type occurring during the slightest physical effort, also periodically at resting activity. The pain intensified. A significant deterioration occurred 2 weeks earlier. Coronary artery disease was diagnosed 5 years before and its first symptom was non-ST-elevation myocardial infarction (NSTEMI). The patient was also treated for hypertension and diabetes. Thorough invasive diagnostics of the coronary arteries was made. Coronary artery bypass surgery was necessary. After previous cardiac and anesthetic consultation,

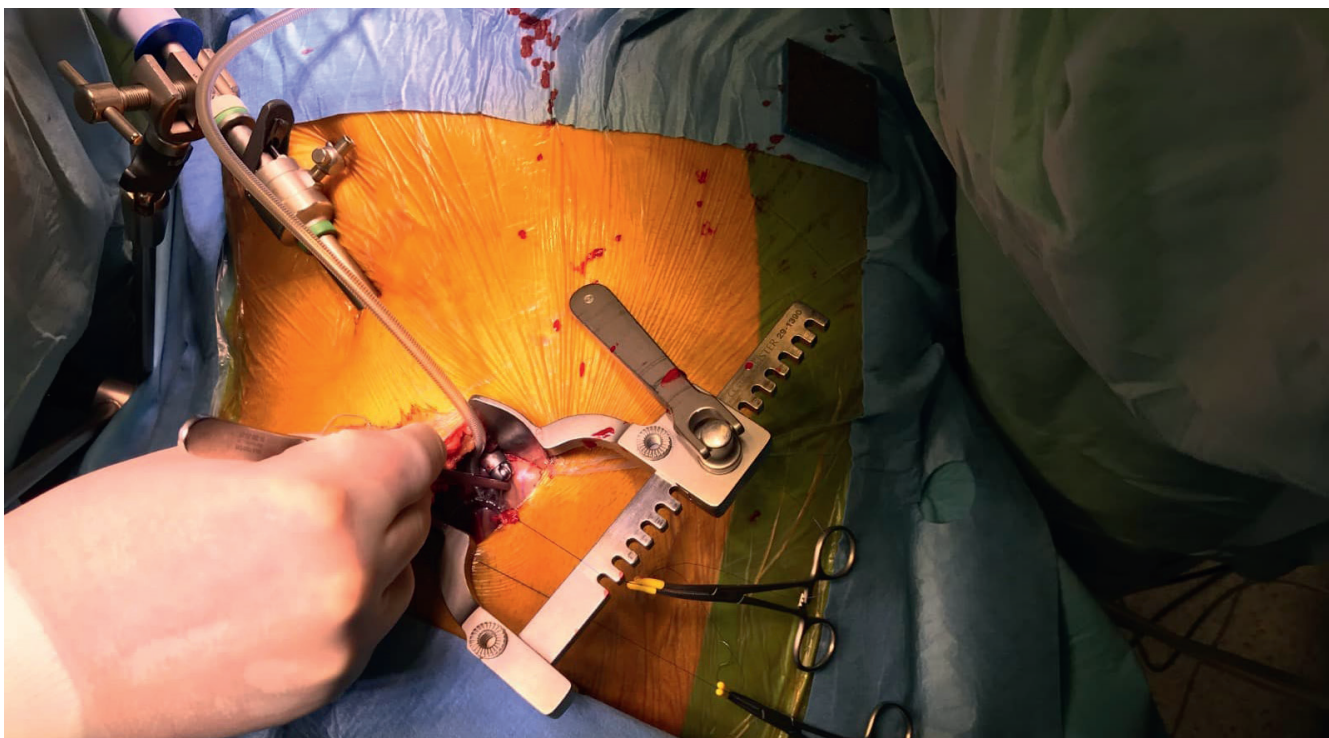


Fig. 3. Coronary artery bypass grafting using the MIDCAB method

Ryc. 3. Pomostowanie aortalno-wieńcowe metodą MIDCAB

the patient was eligible for surgery. The surgery began with sternotomy, followed by dissecting free the right internal thoracic artery (LITA) and the saphenous vein. The procedure was performed using the CBP method. After sutures had been placed on the ascending aorta and the right atrium, cannulation for CBP was performed. Cardiopulmonary bypass was initiated and the aorta was clamped in normothermia. Intermittent cold-blood cardioplegia was used to protect the myocardium. Three bypasses were performed. Cardiopulmonary bypass was completed without complications, after a total duration of 1.5 h. The measurement with a flow meter revealed normal flows in the bypasses. Due to low blood count, 2 units of packed red blood cells were transfused. From the moment of opening the chest area, the total duration of the procedure was 4 h. After hemostasis, the rib cage was closed with a surgical drain. The patient, cardiovascularly stable and mechanically ventilated, was transferred to the postoperative ward for further treatment. The patient was extubated 12 h after surgery. After 2 days, the patient was transferred from the intensive care unit to the postoperative care unit. The time of surgery and the use of CBP resulted in prolonged hospitalization in the ward and longer intubation. There was also the need to transfuse blood products, which may be associated with late post-transfusion reactions.

Patient considered eligible for OPCAB

The second case described: A 64-year-old patient admitted to the ward for the treatment of polyvascular (coronary artery) disease, after ST-elevation myocardial infarction (STEMI) and the PCI procedure performed on July 27, 2019. On the NYHA (New York Heart Association – a scale used for classifying the extent of heart failure) scale, the patient was placed in the 2nd category and his body mass index (BMI) was 29. The patient had been treated in an outpatient clinic for diabetes (the insulin therapy) for 20 years and for hypertension for 30 years. Moreover, the patient had a history of hypercholesterolemia. On August 2, 2019, OPCAB was performed on the patient. The operation began with complete sternotomy, 2 thoracic arteries (right and left) were taken and full arterial revascularization was performed without disturbing the aorta. The absence of the need for taking materials from the lower extremities to form bypasses, in addition to a lesser tissue disruption (chest only) also reduced the risk of infection and difficulties in wound healing. Control shunt flows were normal. The course of the surgery was stable, there was no need to use catecholamines, blood transfusions or blood products. From the moment of opening the chest area, the total duration of the procedure was 2.5 h. The patient in stable condition, after a one-day stay in the intensive care unit, was transferred to the postoperative care unit for further treatment. Mechanical ventilation was completed 7 h after the

procedure. Due to favorable anatomical conditions (the possibility of arterial bypasses) and not using the CBP method, the patient was operated on without any complications. In patients with a history of diabetes and obesity, the number of hard-to-heal wounds increases, which causes prolonged hospitalization and general deterioration of the patient's condition. Off-pump coronary artery bypass grafting performed in patients from this group is a solution that minimizes the effects of CBP, such as the risk of strokes, post-transfusion complications or myocardial dysfunction.

Patient considered eligible for MIDCAB

Third patient: A 69-year-old patient with single-vessel coronary artery disease admitted to the cardiac surgery clinic for surgical treatment. A medical history of the patient showed he suffered from long-term hypertension, had undergone an ischemic stroke in 2008 and was being treated for glomerulonephritis – he was in good condition at that time. EuroSCORE II and Clinical Frailty Scale scores were 7.43% and 6 points, respectively. Echocardiography did not reveal any valvular defects. In coronary angiography, the left main coronary artery (LMCA) showed no abnormalities and in LAD, the left segment was contracted. Two years earlier, effective PCI was performed in the area of the right coronary artery (RCA). The patient was prepared for surgery. Standard Allen's test of the arteries of the left forearm was performed along with the Doppler flow assessment of the radial and ulnar arteries. The patient was placed on his back with the left half of his chest elevated. The procedure started with the completely endoscopic collection of LIMA with a harmonic scalpel. Five-centimeter lateral left minithoracotomy was performed. The LIMA-to-LAD anastomosis was performed using a frame for minimally invasive surgeries and the Octopus tissue stabilizer. An ultrasound flow assessment – which confirmed a correct hemodynamic recording – was performed within the vessel. Hemostasis was performed. A surgical drain was inserted into the left pleural cavity. The chest was closed in layers. The procedure took 2 h. Full blood count did not show any need to transfuse blood products. The patient was transferred to the postoperative ward in stable condition for further treatment. The patient was extubated after 6 h. No major pain was observed. The left upper limb did not show any signs of peripheral neuropathy or bleeding. Central vascular accesses were removed. Control examinations were normal. The patient did not report any resting and exercise stenocardial complaints throughout his hospital stay and was discharged home in stable condition.

The surgical procedure the patient underwent has a beneficial effect on the patient's entire convalescence period. Although it does not require complete sternotomy and cutting large skin areas, the same effect is achieved as with the CABG and OPCAB surgeries. The patient does

not need to undergo a lengthy rehabilitation process and caring for maintaining chest stability is not necessary.

Discussion

The comparison of heart surgery methods proves how dynamically knowledge and clinical practice change. The classic method of surgical revascularization of the heart – widely used and known for over 30 years – is CABG. The heart is stopped during this procedure, which provides the surgeon with a comfortable, stable operating field, easy access to all anatomical sites of the heart and good conditions for the treatment of the coronary arteries, without any hemodynamic impairment.⁹

Cardiopulmonary bypass proved to be a source of complications in the further treatment of patients. Clinically relevant SIRS includes problems concerning the central nervous system (strokes), the deterioration of the renal function, respiratory failure, myocardial ischemia, and early heart failure. Hazards resulting from the use of CBP affected the development and introduction of less invasive new solutions and techniques – coronary artery bypassing on a beating heart, without stopping the heart. It turned out that reduction in invasiveness had great benefits, such as reducing the number of early postoperative complications (especially in high-risk patients). The OPCAB surgery is technically more difficult and is not performed by every cardiac surgery center. In addition to the difficult performance of anastomoses, it requires the excellent hemodynamic management of patients by experienced cardiac anesthesiologists. The effectiveness, safety and scope of OPCAB have been improved with the use of stabilizers and shunts that maintain the coronary flow. Despite these advantages, some studies indicate that OPCAB is associated with reduced scope and accessibility to all coronary arteries on a beating heart, and with a worse quality of anastomoses due to a mobile operating field.^{14,15}

In studies conducted by Kucewicz et al., 2 methods of myocardial revascularization were compared – CABG and OPCAB.¹⁶ They examined 993 patients after coronary artery bypass surgery, including 458 operated on with the OPCAB approach and 505 with CBP. Both groups did not differ significantly in terms of age, height, body weight, and the perioperative risk on the EuroSCORE II scale. The researchers found several differences between these 2 methods in relation to the patient's hospitalization and their condition during the procedure. On average, patients after the OPCAB surgery left the cardiac surgery ward 24 h earlier. They were also mechanically ventilated in a shorter time-span (during and after the procedure); the transfusion of blood and blood products was less frequently needed. The same observations were made in this paper. The disadvantages of this method are fewer vascular anastomoses and the need to use special-

ist cardiac stabilization devices that are not available in every operating suite.¹⁶

In their research paper, Birla et al. compared the MIDCAB and OPCAB techniques.¹⁷ The survey involved 166 patients, including 75 who underwent the MIDCAB procedure and 91 – OPCAB. The analysis of the data shows that the minimally invasive method had a positive effect on shortening the patient's hospitalization time and reduced the need for the transfusion of blood products. The procedure may become the leading method of CABG as compared to the classic bypassing method. Revascularization without CBP provides more opportunities for the overall assessment of other coronary vessels and cardiac anatomy, and is characterized by greater access to the operating field. The surgeon has the entire field of vision and the assurance that they did not damage any structures and tissues before the closure of the chest. The minimally invasive method requires great dexterity and experience from the operator. This method is also beneficial to patients, as there is no need for complete sternotomy, and thus long rehabilitation as well as maintaining chest stability can be avoided.¹⁷

In their research paper, Keeling et al. compared 2 methods of surgery – OPCAB and CABG.¹⁸ The surgeries were performed in patients with a low ejection fraction. The authors came to the following conclusions: In patients eligible for surgery without the use of the CBP method, there was a higher perioperative risk than in patients undergoing the CABG procedure; however, in the overall summary, only single incidents of intraoperative complications occurred in the former group. Analyzing the literature and own research, the authors recommend OPCAB for patients with a low ejection fraction, as it is characterized by lower mortality, fewer neurological complications and shorter hospitalization time.¹⁸

Polish researchers – Piątek et al. – also mention the advantages of minimally invasive surgeries without the use of CBP.¹⁹ More than half of the respondents were operated employing the minithoracotomy approach and others with the use of complete sternotomy. It has been confirmed that both methods are equally safe for the patient's life and health. The authors did not notice any differences in the number of intraoperative complications, reoperations or increased mortality. Both the MIDCAB and OPCAB methods have been widely used in patients with numerous comorbidities.¹⁹

Conclusions

Coronary artery bypass surgeries are performed in increasingly older patients with a history of various comorbidities.

The standard coronary artery bypass surgery using CBP is more and more often replaced with OPCAB be-

cause of fewer complications, the rarer need for blood transfusion and a lower risk of strokes.

The MIDCAB procedure is minimally invasive and increasingly replaces the coronary artery bypass surgery using CBP or OPCAB.

The disadvantages of the MIDCAB procedure include the insufficient visibility of the operating field, the possibility of treating the patient with the obstruction of only single coronary artery as well as the need to use specialized devices.

Each of the abovementioned methods of surgery are applicable in different cases; however, the choice always depends on anatomical indications, the severity of coronary artery disease and the operator's decision.

ORCID iDs

Sabina Dyszy  <https://orcid.org/0000-0003-1090-9456>

Martyna Kluszczyńska  <https://orcid.org/0000-0003-1090-9456>

References

- Skalski JH. Początki chirurgii serca. Część I. Zranienie serca. *Szlachetne Zdrowie – Kwartalnik Śląskiego Centrum Chorób Serca*. 2003;5:14–15.
- McLean J. The discovery of heparin. *Circulation*. 1959;19(1):75–78. doi:10.1161/01.cir.19.1.75
- Noszczyk W, ed. *Zapalenia zakrzepowe żył kończyn*. Warsaw, Poland: Dział Wydawnictw Akademii Medycznej; 1984.
- Gibbon JH Jr. Application of a mechanical heart and lung apparatus to cardiac surgery: Recent advances in cardiovascular physiology and surgery. *Minn Med*. 1954;37(3):171–185.
- Shroyer AL, Grover FL, Hattler B, et al. On-pump versus off-pump coronary-artery bypass surgery. *N Engl J Med*. 2009;361(19):1827–1837. doi:10.1056/NEJMoa0902905
- Dytfeld D, Dyszkiewicz W, Meissner R. Rozwój pomostowania aortalno-wieńcowego oraz sposobów śródoperacyjnej protekcji mięśnia sercowego. *Now Lek*. 2006;75(4):404–406. https://jms.ump.edu.pl/uploads/2006/4/404_4_75_2006.pdf. Accessed on May 18, 2020.
- Zembala M, Tajstra M, Zembala M, et al. Czy nadszedł już czas na rewaskularyzację hybrydową w wielonaczyniowej chorobie wieńcowej z udziałem kardi chirurga i kardiologa? *Kardiologia Pol*. 2009;67(7):817–822. <https://www.mp.pl/kardiologiapolska/en/node/9979/pdf>. Accessed on May 18, 2020.
- Sokal A, Zembala M, Radomski A, et al. A differential release of matrix metalloproteinases 9 and 2 during coronary artery bypass grafting and off-pump coronary artery bypass surgery. *J Thorac Cardiovasc Surg*. 2009;137(5):1218–1224. doi:10.1016/j.jtcvs.2008.11.004
- Suwalski G, Shroyer AL, Grover FL, Hattler B; Veterans Affairs Randomized On/Off Bypass (ROOBY) Study Group. On-pump versus off-pump coronary-artery bypass surgery. *N Engl J Med*. 2009;361(19):1827–1837. doi:10.1056/NEJMoa0902905
- Benetti FJ, Geffner L, Naselli G, Wodd M. Direct myocardial revascularization without extracorporeal circulation: Experience in 700 patients. *Chest*. 1991;100(2):312–316. doi:10.1378/chest.100.2.312
- Calafiore AM, Giammarco GD, Teodori G, et al. Left anterior descending coronary grafting via left anterior small thoracotomy without cardiopulmonary bypass. *Ann Thorac Surg*. 1996;61(6):1658–1665. doi:10.1016/0003-4975(96)00187-7
- Naunheim KS, Barner HB, Fiore AC. Results of internal thoracic artery grafting over 15 years: Single versus double grafts. 1992 update. *Ann Thorac Surg*. 1992;53:716–718. [https://www.annals-thoracicsurgery.org/article/0003-4975\(92\)90346-6/pdf](https://www.annals-thoracicsurgery.org/article/0003-4975(92)90346-6/pdf). Accessed on May 18, 2020.
- Loop FD. Internal thoracic artery grafts: Biologically better coronary arteries. *N Eng J Med*. 1996;334(4):263–265. doi:10.1056/NEJM199601253340411
- Zaouter C, Imbault J, Labrousse L, et al. Association of robotic totally endoscopic coronary artery bypass graft surgery associated with a preliminary cardiac enhanced recovery after surgery program: A retrospective analysis. *J Cardiothorac Vasc Anesth*. 2015;29(6):1489–1497. doi:10.1053/j.jvca.2015.03.003
- Gil R, Dudek D, ed. *Ostre zespoły wieńcowe*. Poznań, Poland: Termedia; 2015.
- Kucewicz E, Puzio J, Wojarski J, et al. Effects of on pump and off pump surgery on early results of coronary artery bypass grafting. *Anesth Int Ter*. 2016;3:140–143.
- Birla R, Patel P, Aresu G. Minimally invasive direct coronary artery bypass grafting compared to coronary surgery outside the pump by sternotomy. *Ann R Coll Surg Engl*. 2013;95(7):481–485. doi:10.1308/0003588413X13629960047119
- Keeling WB, Williams ML, Slaughter MS, Zhao Y, Puskas JD. Off-pump and on-pump coronary revascularization in patients with low ejection fraction: A report from the society of thoracic surgeons national database. *Ann Thorac Surg*. 2013;96(1):83–89. doi:10.1016/j.athoracsurg.2013.03.098
- Piątek J, Kędziora A, Janusz K, et al. Minimally invasive coronary artery bypass as a safe method of surgical revascularization: The step towards hybrid procedures. *Adv Interv Cardiol*. 2017;13(4):320–325. doi:10.5114/aic.2017.71614