İnönü Üniversitesi Sağlık Hizmetleri Meslek Yüksekokulu Dergisi, ISSN: 2147-7892, Cilt 7, Sayı 2 (2019) 211-217

doi: 10.33715/inonusaglik.622822

Review / Derleme

ACUTE KIDNEY INJURY DUE TO CARDIOVASCULAR SURGERY

Kalp Damar Cerrahisine Bağlı Akut Böbrek Yaralanması

Mahmut PADAK *Reşat DİKME* *Ömer GÖÇ*

Harran Üniversitesi Sağlık Hizmetleri Meslek Yüksekokulu, Şanlıurfa

Geliş Tarihi / Received: *20.09.2019* ***Kabul Tarihi / Accepted:*** *06.12.2019* ***Yayım Tarihi / Published:*** *25.12.2019*

ABSTRACT

Cardiopulmonary bypass (CPB) is an extracorporeal circulatory model consisting essentially of a pump, reservoir and oxygenator. At the beginning of CPB, blood of the patient flows into the extracorporeal circulation, which does not contain the endothelial surface, from the patient and initiates the inflammatory process, that is developed by the cellular, extracellular or humoral components of the blood and this process varies according to the patient's genotype, peroperative parameters and complexity of the pathology. Acute renal injury among patients undergoing cardiac surgery appears to be associated with poor prognosis and increased mortality. Acute kidney injury (AKI) is a condition that increases the common mortality and morbidity in intensive care unit (ICU) patients and adversely affects the clinical course.

Keywords: Cardiopulmonary bypass, acute kidney injury, dialysis

ÖZ

Kardiyopulmoner baypas (KPB), bir ekstrakorporeal dolaşım modeli olup esas olarak bir pompa, rezervuar ve oksijeneratörden oluşur. KPB'ın başlangıcında kan hastadan bu endotelyal yüzey içermeyen ekstrakorporeal dolaşıma katılarak hastanın genotipi, peroperatif parametreler ve patolojinin kompleksitesine göre kalp cerrahisi sonrasında değişik derecelerde gelişen ve kanın hücresel, hücre dışı veya humoral bileşenleri tarafından yönetilen inflamatuvar süreci başlatır. Kalp ameliyatı geçiren hastalar arasında akut böbrek hasarı oluşumu kötü prognoz ve mortalite artışı ile ilişkili görünmektedir. Akut böbrek hasarı (ABH), yoğun bakım hastalarında sık karşılaşılan mortalite ve morbiditeyi arttırarak klinik seyri olumsuz yönde etkileyen bir tablodur.

Anahtar kelimeler: Kardiyopulmoner baypas, akut böbrek hasarı, diyaliz

Mahmut PADAK ✉, mpadak@harran.edu.tr

Harran Üniversitesi Sağlık Hizmetleri Meslek Yüksekokulu, Şanlıurfa

How to cite this article / Bu makaleye atıf yapmak için: Padak M, Dikme R, Göç Ö. Acute Kidney Injury Due to Cardiovascular Surgery. İnönü Üniversitesi Sağlık Hizmetleri Meslek Yüksekokulu Dergisi, 2019; 7(2): 211-217. doi: 10.33715/inonusaglik.622822

INTRODUCTION

Critical diseases and major surgical interventions as trauma burns, sepsis cancer, heart disease and liver failure are among the causes of acute renal failure (ARF). Studies conducted over the past few years have shown that ARF is frequently encountered in patients in the intensive care unit (ICU) (De Mendonça et al., 2000; Dimov, Usmani, Noor & Kumar, 2006).

During cardiac surgery under cardiopulmonary bypass (CPB), the functions of the heart and lungs must be stopped and blood in the heart should be evacuated. During this operation, the functions of the heart and lungs are provided by a device called a heart-lung machine outside the body. Cardiopulmonary bypass is a system in which the heart's pump function and the gas exchange function of the lungs are provided by a pump oxygenator that is temporarily connected to the patient's vascular system. In this system, also called extracorporeal circulation, carbon dioxide is taken from venous blood from the heart and oxygen is added and sent back to a large artery. Extracorporeal circulatory circuit is composed of; arterial and venous lines, venous reservoir, pump, oxygenator, heat exchanger, vent and cardiotomy reservoir, aspiration systems, filters, ultrafiltration filter and cardioplegia system parts. When CPB is fully supplied, extracorporeal equipment provides both circulation and ventilation. However, this method is nonphysiological since blood flow is often nonpulsatile and has low pressure than normal (Ismail & Miskolczi, 2019).

Acute renal injury among patients undergoing cardiac surgery appears to be associated with poor prognosis and increased mortality. Acute Kidney Injury (AKI) affects approximately 20% of all hospitalized patients (National Confidential Enquiry into Patient Outcomes and Death (NCEPOD), 2009) and has significant socioeconomic effects on both long-term hospitalization and health (Hsu et al., 2009; Kerr, 2011).

Long-term studies have shown that AKI attacks can significantly increase both the risk of developing chronic kidney disease and premature death (Lassnigg et al., 2004). In addition, 2 to 6% of patients require dialysis because of AKI development after cardiac surgery, indicating that a significant number of kidney diseases may occur (Rosner & Okusa, 2006; Thiele, Isbell & Rosner, 2015).

Although extracorporeal circulation (ECC) has increased in recent years, it is mandatory to use it frequently in some cases of cardiac surgery. In open heart surgery, the functions of the heart and lungs need to be stopped and the blood in the stopped mechanism, should be transferred to a different system. Although this system is non-physiological as it does not carry the functions of a complete human body physiology, as organs and related systems may

function only with the help of extracorporeal circulation, ECC in heart surgery is a preferred method (Bassin & Bell, 2016).

Kidney deterioration after bypass is a relatively common event. Approximately 25% of cardiac output is delivered to the kidneys. Endocrine changes due to dilution after bypass may reduce renal function. Also the kidneys have to filter out damaged erythrocytes and other damaged elements in the bypass lines. The destruction of erythrocytes (hemolysis) causes the release of hemoglobin into the plasma. This can lead to hemoglobin cylinders. If the amount of released hemoglobin is too high, the kidney cannot reabsorb the filtered hemoglobin and hemoglobinuria occurs. Preoperative poor renal function is the best indicator of postoperative failure as in the lungs (O'Neal**,** Shaw & Billings, 2016)**.**

Acute kidney injury (AKI) is a common and serious complication that increases short-term mortality in hospitalized patients (Uchino et al., 2006; Ricci, Cruz & Ronco, 2008). Patients with severe forms of AKI need acute dialysis and the incidence of AKI (AKI-D) requiring dialysis in the US has increased rapidly compared to previous years (Hsu, McCulloch, Dudley, Lo & Hsu, 2013).

Perioperative fluid management may affect postoperative renal function. Normal saline solution is the most commonly used intravenous solution in perioperative fluid management (Awad, Allison & Lobo, 2008). However, recent clinical studies have shown that excessive saline-based solution can cause hyperchloremic acidosis, which can lead to excessive renal blood flow and poor clinical outcomes (McCluskey, 2013; Reid, 2003). In a previous human study, normal saline intravenous infusion led to reduction in renal blood flow rate and renal cortical tissue perfusion (Freeland, Jahromi, Duvall & Mancini, 2015). In contrast, other studies have shown that stable crystalloid and colloid solutions can prevent the development of hyperchloremic metabolic acidosis and increase the mean level of renal cortical tissue perfusion compared to saline-based solutions (Base et al., 2011; Chowdhury et al., 2014). After cardiac surgery, renal replacement therapy (RRT) is required between 1.6% and 7.7%, which may lead to an increase in mortality in these patients (Coppolino, Presta, Saturno & Fuiano, 2013; Perez et al., 2009). Many perioperative risk factors including advanced age (Freeland, 2015; Ried, 2011), angiography and prolonged surgical time, blood transfusion, and preoperative high serum creatinine have been reported as predictors of cardiac surgery-related AKI (Hu et al., 2013).

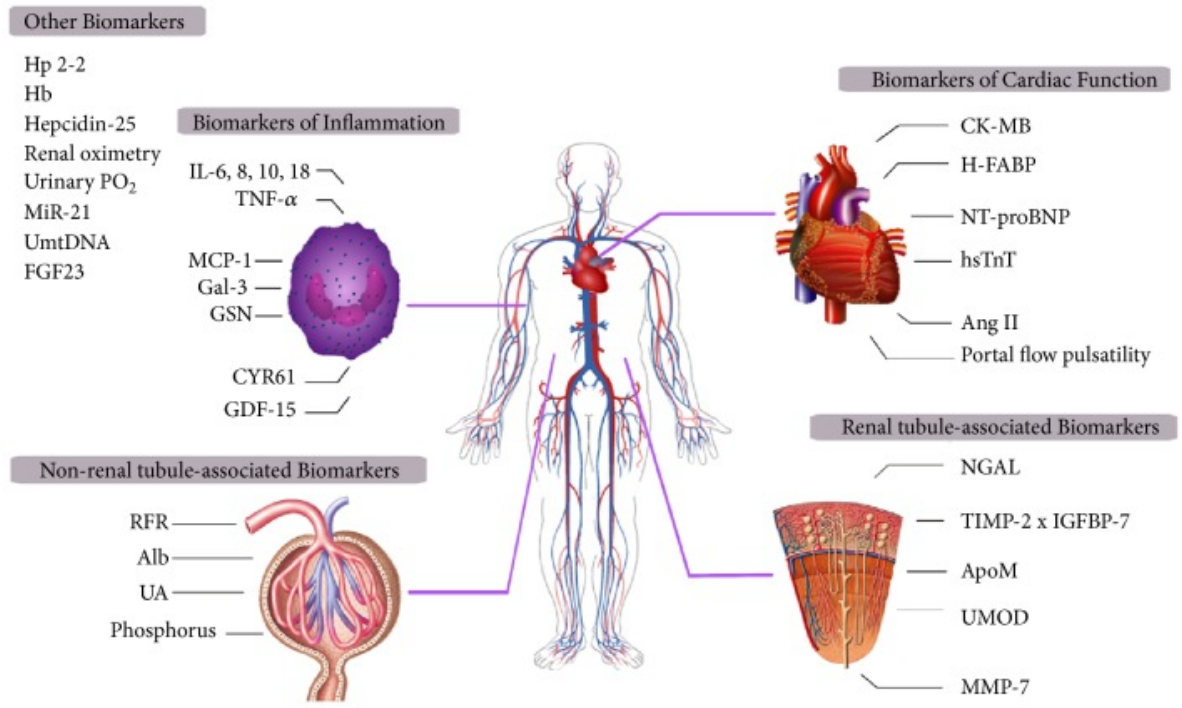

Figure 1: Biomarkers of cardiac surgery-associated acute kidney injury (CSA-AKI). Biomarkers of CSA-AKI are divided into four categories including renal tubule-associated biomarkers, nonrenal tubule-associated biomarkers, biomarkers of cardiac function, and biomarkers of inflammation. Other biomarkers that cannot be classified into the above types are listed as one category at the top left. *CK-MB:* creatine kinase-MB, *H-FABP:* heart fatty acid binding protein, *NT-proBNP:* N-tnd persistederminal prohormone of brain natriuretic, *AngII:* angiotensin II, *NGAL:* neutrophil gelatinase-associated lipocalin, *TIMP-2:* tissue inhibitor of metalloproteinases 2, *IGFBP-7:* insulin-like growth factor-binding protein 7, *ApoM:* apolipoprotein M, *UMOD:* urinary uromodulin, *MMP-7:* matrix metalloproteinase-7, *IL:* interleukin, *TNF-α:* tumor necrosis factor alpha, *MCP-1:* monocyte chemotactic protein-1, *Gal-3*: galectin-3, *GSN:* gelsolin, *CYR61:* cysteine-rich protein 61, *GDF-15:* growth differentiation factor 15, *RFR:* renal functional reserve, *Alb:* albumin, *UA:* uric acid, *Hp2-2:* 2-2 phenotype of haptoglobin, *Hb:* hemoglobin, *PO_2:* oxygen tension, *MiR-21:* microRNA-21, *UmtDNA:* urinary mitochondrial DNA, and *FGF23:* fibroblast growth factor 23 (Binbin, Jianghua, Yi, 2019).

Acute renal failure (ARF) is a frequent serious condition in patients undergoing cardiovascular surgery. The risk factors of ARF are multiple and include; age, coexisting diabetes, preoperative hypovolemia, a preoperative serum creatinine level over 2 mg/dl, systemic anesthesia, peroperative blood loss, hypotension, hemolysis, abdominal aortic surgery, aortic valve surgery with coronary bypass, emergent cardiac surgery, preoperative intraaortic balloon pump requirement.

DISCUSSION AND CONCLUSION

AKI is defined as sudden deterioration in renal function and the accumulation of urea and other nitrogen waste products in the body, as well as the deterioration of extracellular volume and electrolytes.

Surgical interventions and anesthesia cause inflammatory response in all patients. During open heart surgery, this response is more pronounced since cardiopulmonary bypass

(CPB) is a non-physiological process. During cardiopulmonary bypass, blood elements are in contact with foreign matter and surfaces. Blood products in contact with nonendothelial surfaces are activated and the release of vasoactive mediators is stimulated (Aldea et al., 2002). Capillary permeability increases, hemolysis and hemodilution develops. Hemodilution causes fluid displacement between compartments, fluid retention and denaturation of plasma proteins. Simultaneous activation of the coagulation system occurs. As a result, systemic inflammatory response syndrome occurs (Warren, 2009; Day, 2005). Significant pathological changes in cardiac, pulmonary, renal, and cerebral functions and major complications such as organ dysfunction may occur (Lindholm, 2004; Serrano, 2010).

There have been significant changes in acute renal failure (ARF) terminology recently. acute kidney injury (AKI) has largely been replaced by ARF. The reason for this change is the recent studies which showed that acute and relatively mild kidney damage can also lead to significant clinical changes by effecting urine output and blood biochemistry. The term ARF is used for severe AKI requiring more RRT (Khwaja , 2012; Chertow et al., 2005).

Advanced age, diabetes, surgery with ECC, red blood cell transfusion and long-term mechanical ventilation are among the risk factors that will accelerate AKI development. Many mechanisms as altered renal blood flow, hypoperfusion, inflammation, pulsatile flow loss, ischemia, decreased autoregulation and nephrotoxic drugs have been proposed for the development of AKI after cardiac surgery (Binbin, Jianghua & Yi, 2019).

The development of acute renal injury is due to poor postoperative outcomes and high mortality rates in patients undergoing isolated coronary artery bypass graft (CABG). There are many mechanisms related to AKI development, including ischemic reperfusion lesion, nephrotoxin release, hemolysis, oxidative stress, systemic inflammatory responses, endothelial lesion and cytokine secretion that produce tubular cell damage (Coppolino, Presta, Saturno & Fuiano, 2013).

For the prevention of AKI; risk determination of surgical procedure in the presence of early biomarkers, hemodynamics monitorization, real-time Glomerular Filtration Rate (GFR) measurements with renal perfusion and intracapsular membrane pressure monitorizations, perhaps stemcells with may be considered (Bolliger & Fassl, 2018; Nadim et al., 2018).

REFERENCES

Aldea GS, Soltow LO, Chandler WL, Triggs CM, Vocelka CR, Crockett GI. Limitation of thrombin generation, platelet activation, and inflammation by elimination of cardiotomy suction in patients undergoing coronary artery bypass grafting treated with heparin-bonded circuits, J Thorac Cardiovasc Surgery, 2002;123(4):742- 55.

Awad S, Allison SP, Lobo DN. The history of 0,9 % saline, Clin Nutr, 2008;27:179–88.

Base EM, Standl T, Lassnigg A, Skhirtladze K, Jungheinrich C, Gayko, D. Efficacy and safety of hydroxyethyl starch 6 % 130/0.4 in a balanced electrolyte solution (Volulyte) during cardiac surgery, J Cardiothorac vascular anesthesia, 2011;25:407–14.

Bassin L, Bell D. Temporary extracorporeal bypass modalities during aortic surgery, Best Pract Res Clin Anaesthesiol, 2016;30(3):341-57.

Binbin Wu, Jianghua Chen, Yi Yang. Biomarkers of Acute Kidney Injury after Cardiac Surgery: A Narrative Review, Biomed Res Int, 2019;11. https://doi.org/10.1155/2019/7298635, PMCID: PMC6620851 PMID: 31.346.523

Bolliger D, Fassl J. Avoiding acute kidney injury after cardiac surgery: Simple and Easy? J Cardiothorac vascular anesthesia. 2018;32(1):223-4.

Chertow GM, Burdick E, Honour M, Bonventre JV, Bates DW. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients, J Am Social Nephrol, 2005;16:3365-3370.

Chowdhury AH, Cox EF, Francis ST, Lobo DN. A randomized, controlled, double-blind crossover study on the effects of 1-L infusions of 6 % hydroxyethyl starch suspended in 0.9 % saline (Voluven) and a balanced solution (Plasma Volume Redibag) on blood volume, renal blood flow velocity, and renal cortical tissue perfusion in healthy volunteers, Ann Surg, 2014;259:881–7.

Coppolino G, Presta P, Saturno L, Fuiano G. Acute kidney injury in patients undergoing cardiac surgery, J Nephrol. 2013;26(1):32-40.

Day JR., Taylor, KM. The systemic inflammatory response syndrome and cardiopulmonary bypass. International J Surgery, 2005;3:129-40.

De Mendonca A, Vincent JL, Suter PM, et al. Acute renal failure in the ICU: risk factors and outcome evaluated by the SOFA Score, Intensive care medicine, 2000;26:915-21.

Dimov V, Usmani A, Noor S, Kumar A. Who is at risk for developing acute renal failure after surgery? IMPACT consults. Proceedings of the 2nd Annual Cleveland Clinic Perioperative Medicine Summit, Cleveland Clinic journal of medicine, 2006;73:12-13.

Freeland K, Jahromi AH, Duvall LM, Mancini MC. Postoperative blood transfusion is an independent predictor of acute kidney injury in cardiac surgery patients, Journal Nephropathol, 2015;4(4):121-6.

Hsu CY, Chertow GM, McCulloch CE, Fan D, Ordonez JD, Go AS. Nonrecovery of kidney function and death after acute on chronic renal failure, Clin Journal Am Soc Nephrol, 2009;4(5):891–8.

Hsu RK, McCulloch CE, Dudley RA, Lo LJ, Hsu CY. Temporal changes in incidence of dialysis-requiring AKI, Journal Am Soc Nephrol, 2013;24:37–42.

Hu Y, Li Z, Chen J, Shen C, Song Y, Zhong Q. The effect of the time interval between coronary angiography and on-pump cardiac surgery on risk of postoperative acute kidney injury: a meta-analysis, Journal Cardiothorac Surgery, 2013;8(1):178.

Ismail A, Miskolczi SY. Cardiopulmonary Bypass, Treasure Island (FL): StatPearls Publishing, 2019.

Khwaja A. KDIGO Clinical Practice Guideline for Acute Kidney Injury, Nephron Clinical Practice, 2012;120:c197-c184. http://dx.doi.org/10.1159%2F000339789

Kerr M. The economic impact of acute kidney disease [NHS Kidney Care report], 2011.

Lassnigg A, Schmidlin D, Mouhieddine M, Bachmann, LM, Druml W, Bauer P. Minimal changes of serum creatinine predict prognosis in patients after cardiothoracic surgery, a prospective cohort study, Journal Am Soc Nephrol, 2004;15(6):1597–605.

Lindholm L, Westerberg M, Bengtsson A, Ekroth R, Jensen E, Jeppsson A. closed perfusion system with heparin coating and centrifugal pump improves cardiopulmonary bypass biocompatibility in elderly patients, Ann Thorac Surg, 2004;78:2131-8.

McCluskey SA, Karkouti K, Wijeysundera D, Minkovich L, Tait G, Beattie WS. Hyperchloremia after noncardiac surgery is independently associated with increased morbidity and mortality, a propensity-matched cohort study, Anesth Analg, 2013;117:412–21.

Nadim MK, Forni LG, et al. Cardiac and vascular surgery-associated acute kidney ınjury. The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group, J Am Heart Assoc, 2018;7.

National Confidential Enquiry into Patient Outcomes and Death (NCEPOD) Report(2009). Adding Insult to Injury.

O'Neal JB, Shaw AD, Billings FT. Acute kidney injury following cardiac surgery: current understanding and future directions, Crit Care, 2016;20(1):187.

Perez Valdivieso JR, Monedero P, Vives M, Garcia Fernandez N, Bes Rastrollo M, GEDRCC (Grupo Espanol de Disfuncion Renal en Cirugia Cardiaca). Cardiac-surgery associated acute kidney injury requiring renal replacement therapy, A Spanish retrospective case-cohort study, BMC Nephrol, 2009;10(1):27.

Reid F, Lobo DN, Williams RN, Rowlands BJ, Allison SP. (Ab)normal saline and physiological Hartmann's solution: a randomized double-blind crossover study, Clin Science, 2003;104:17–24.

Ricci Z, Cruz D, Ronco C. The RIFLE criteria and mortality in acute kidney injury: A systematic review, Kidney Int, 2008;73:538–546.

Ried M, Puehler T, Haneya A, Schmid C, Diez C. Acute kidney injury in septua- and octogenarians after cardiac surgery, BMC Cardiovasc Disord, 2011;11(1):52.

Rosner MH, Okusa MD. Acute kidney injury associated with cardiac surgery, Clin J Am Soc Nephrol, 2006;1(1):19–32.

Serrano CV Jr, Souza JA, Lopes, NH, Fernandes JL, Nicolau JC, Blotta MH, et al. Reduced expression of systemic proinflammatory and myocardial biomarkers after offpump versus on-pump coronary artery bypass surgery: a prospective randomized study, Journal of critical care, 2010;25(2):305-312.

Thiele RH, Isbell JM, Rosner MH. AKI associated with cardiac surgery, Clin J Am Soc Nephrol, 2015;10(3):500–14.

Uchino S, Bellomo R, Goldsmith D, Bates S, Ronco C. An assessment of the RIFLE criteria for acute renal failure in hospitalized patients, Crit Care Med, 2006;34:1913–1917.

Warren OJ, Smith AJ, Alexiou C, Rogers PL, Jawad N, Vincent C, et al. The inflammatory response to cardiopulmonary bypass: part 1--mechanisms of pathogenesis, J Cardiothorac Vasc Anesth, 2009;23:223-31.