|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **eTable 1. Overview of studies assessing the association between lactate and various outcomesa,b** | | | | | | | | | | | |
| **Study** | **Sites** | **Period** | **Designc** | **Inclusion criteria** | **Exclusion criteria** | **Sample size** | **Lactated** | | | **Outcome(s)** | **Results** |
| **Where** | **When** | **High?** |
| Schütz  1998 1 | 1 | Oct. 1992 – Dec. 1996 | NR | Open heart surgery | - | 4,640 | Serum | NR | NR | Mesenteric ischemia | 0.3% developed  mesenteric ischemia all with elevated lactate. Lactate not reported in those without mesenteric ischemia |
| Demers  2000 2 | 1 | Jan. – Dec. 1995 | Retrospective | Cardiac surgery with CPB | Intraoperative death, pre-operative lactate > 2.5, missing data | 1,259 | Arterial | Highest during surgery | > 4.0 | Hospital mortality, post-operative complications, LOS | 18% with high lactate. 11.0% versus 1.4% mortality, more complications, longer LOS |
| Davies  2001 3 | 1 | 2-year period | Retrospective | Cardiac surgical patients with IABP | - | 39 | Serum | Within 8 hours of IABP support | > 10 | Survival to discharge, inability to wean from IABP | Associated with both outcomes. 100% PPV and 53% NPV for mortality |
| Rao  2001 4 | 1 | 1983 - 1996 | Prospective | CABG | - | 623 | Difference between arterial and coronary sinus | During surgery | 0.4  (lactate release) | Low cardiac output syndrome (IABP or inotropes) | Myocardial lactate release higher in those with the outcome and in those that died. AUC: 0.63. |
| Byhahn  2001 5 | 1 | 1-year period | Prospective | Cardiac surgery with CPB | - | 1,116 | NR | NR | NR | Gastro-intestinal complications | 2.1% developed the outcome. Patients with necrotic bowel or hepatic failure had elevated lactate (70% > 10), others normal |
| Klotz  2001 6 | 1 | Nov. 1997 – Jul. 1999 | NR | Cardiac surgery with CPB | - | 20 | Serum | NR | NR | Non-occlusive  mesenteric ischemia | The 20 represented 0.6% of all. Non-significant relationship between severity and lactate |
| Takami  2002 7 | 1 | NR | NR | Cardiac surgery | - | 65 | Trans-pulmonary arterio-venous  difference | Arrival to ICU | NR | Not clearly defined | Associated with duration of intubation and post-op oxygenation |
| Dixon  2003 8 | 1 | NR | Prospective | Elective CABG with CPB | Multiple including high creatinine, bilirubin, temperature or white cell count, airway disease | 40 | Arterial | 4, 7, 10, 13, and 16 hours after CPB | NR | Hours of ventilation, ICU LOS | Not associated with the outcomes |
| Maillet  2003 9 | 1 | 6-month period | Prospective | Cardiac surgery with normo-thermic CPB | Off-pump ssurgery | 325 | Arterial | 4 measurements within the first day of ICU | > 3.0 defined as early and late | ICU mortality, LOS and complications | 21% had early high lactate, 17% had late. Both associated with all outcomes. AUC for ICU mortality for early: 0.85 (69% sens., 81% spec. for predefined cut-off). AUC for late: 0.72 (62% sens., 75% spec. for predefined cut-off) |
| Toraman  2004 10 | 1 | Feb. 1999 – Feb. 2002 | Prospective | CABG | Hepatic dysfunction | 776 | Serum | Within half an hour after surgery | > 2.0 | IABP, inotropes, time to extubation, LOS, mortality | 31% had high lactate. Associated with all outcomes |
| Huwer  2004 11 | 1 | Jan. 1999 - 2002 | Retrospective | Cardiac surgery with CPB | - | 3,600 | Serum | NR | NR | Mesenteric ischemia | 0.6% with mesenteric ischemia. Lactate higher in those with the outcome. |
| Shinde  2005 12 | 1 | NR | Prospective | Valve heart surgery with CPB | Diabetic patients on  phenformin | 82 | Arterial | During and after | Change in lactate > 4 | Duration of inotropic support and mechanical ventilation | High lactate associated with the outcomes |
| Heringlake  2005 13 | 1 | NR | Prospective | CABG | - | 20 | Myocardial | During | NR | Hemodynamics | Some weak and some significant associated with hemodynamic parameters. |
| Hekmat  2005 14 | 1 | Apr. 1999 – Feb. 2003 | Prospective | Cardiac surgery | < 24 hours ICU stay | 2545 | Blood | NR | Various | Mortality | Included in prediction score with good calibration and discrimination |
| Zhang  2006 15 | 1 | Jan. 1996 – Oct. 2004 | NR | ECMO for post-cardiotomy cardiogenic  shock | - | 32 | NR | 48 hours after ECMO | NR | Weaning off ECMO | Higher lactates in the non-weaning group |
| Svenmarker  2006 16 | 1 | 2000 - 2005 | Retrospective | Cardiac surgery with CPB | - | 5,121 | Arterial | Termination  of CPB | > 90th percentile (2.0) | Mortality, LOS, complication | Increase in all outcomes in those with high lactate. Sens.: 54%, spec.: 98% for the cut-off |
| Ranucci  2006 17 | 1 | Sept. 2005 –Dec. 2005 | Prospective | Cardiac surgery with CPB | Pre-operative lactate > 2.0 | 470 | Arterial | During CPB | > 3.0 | LOS, complication, mortality | 5.7% had high lactate. Associated with ICU LOS, prolonged mechanical ventilation, IAPB, morbidity. Not associated with mortality in multivariable analysis |
| Oshima  2007 18 | 1 | Jan. 1991 – Sept. 2008 | Retrospective | Percutaneous cardio-pulmonary support system after cardiac surgery with CPB | - | 13 | Serum | Start of support and 12, 24, 48, 72, and 96 hours after | NR | Weaning from percutaneous support | Only significant difference at 96 hours |
| Abarbanell  2008 19 | 1 | Jan. 1998 – Dec. 2004 | Retrospective | Cardiac surgery for congenital disease (adults) | - | 234 | Blood | Initial and 24 hours | NR | Mortality, LOS, complications | Lactate associated with mortality only in univariate analysis |
| Hauer  2009 20 | 1 | Jan. 2003 – Dec. 2005 | Prospective | Cardiac surgery with CPB | Heart transplant, minimally invasive procedures, preoperative chronic renal  dysfunction | 1,531 | Serum | Hourly, highest within 12 hours | > 1.1 | RRT | 4.6% had the outcome. Higher max. lactate in those with the outcome. Sens.: 49%, Spec.: 99%. Non-survivors on RRT had higher max. lactate |
| Boeken  2009 21 | 1 | Jan. 2004 – Jan. 2008 | Retrospective | IABP after cardiac surgery with CPB | - | 223 | Serum | Max. first 10 hours | > 11 | Mortality, post-operative complications | Associated with the outcomes |
| Gasparovic  2010 22 | 1 | May 2007 – May 2008 | Prospective | CABG with CPB | Valve surgery, redo surgery, prior history of AF | 215 | Radial artery – venous coronary | During CPB | NR | AF | 26% had the outcome. No difference between groups |
| Nogueira  2010 23 | 1 | Jan. 2004 – Aug. 2005 | Prospective | Cardiac surgery with CPB | Missing data, pre-operative sepsis, or death within 3 days | 246 | Arterial or venous | Arrival to ICU, 6 hours and 24 hours | NR | Organ dysfunction of the 3rd post-operative day | Lactate at 24 hours associated with the outcome in multivariable analysis, others not. |
| Rastan  2010 24 | 1 | May 1996 - 2008 | Prospective | ECMO after cardiac surgery | - | 517 | NR | End of surgery, start of ECMO, 24 and 48 hours after | > 4/10 | Mortality | Lactate at all time points associated with outcomes |
| Ranucci  2010 25 | 1 | 2009 | Retrospective | Cardiac surgery with CPB | Missing data, congenital heart disease | 929 | Arterial | ICU admission | > 4 | Mortality | Higher in non-survivors. Remained in multivariable models. For cut-off 4: Sens.: 22%, spec. 98%, PPV: 22%, NPV: 98%. Marginally improved previous prediction scores |
| Kapoor  2011 26 | 1 | NR | Prospective | Elective CABG or valve surgery with CPB | Multiple including pre-operative conditions and concomitant valve and CABG surgery | 40 | Coronary sinus and plasma | Before, during, and after CPB | > 2.9 (myo-cardial lactate) | LOS and inotrope requirements | Longer ICU stay, baseline lactate associated with use of inotropes |
| Noval-Padillo  2011 27 | 1 | Jan. – Dec. 2010 | Prospective | Heart transplant | - | 16 | Arterial | Before, during, and after CPB (ICU arrival) | > 4 | Complication and mortality | 56% had high lactate at ICU arrival. Associated with complications |
| Čanádyová  2012 28 | 1 | May 2000 – May 2006 | Retrospective | Cardiac surgery with re-exploration for bleeding or tamponade | - | 152 | NR | NR | NR | Death | Lactate higher in non-survivors |
| Hu  2012 29 | 1 | Oct. 2007 – Jun. 2008 | Prospective | CABG or valve surgery with CPB with central venous catheter | Multiple including off-pump surgery and intra-operative complications | 60 | Blood | Arrival to ICU and 24 hours later | > 4 | LOS, organ failure | Lactate at 24 hours associated with outcomes, not at ICU arrival. Remained in multivariable analysis |
| Kogan  2012 30 | 1 | Aug. 2009 – Jul. 2011 | Prospective | Cardiac surgery | Off-pump surgery, liver disease | 1,820 | Arterial | Arrival to ICU, every 1-3 hours for 24 hours. Peak value | Mode-rate:  2.2–4.4  High:  > 4.4 | LOS, complications, mortality | Normal: 18%, Moderate: 58%  High: 24%  Associated with some complication, ICU LOS, mortality but not hospital LOS (almost significant) |
| Nicolini  2013 31 | 1 | Feb. 2009 – Aug. 2010 | Prospective | Cardiac surgery | Multiple including off-pump surgery, missing data and pre-operative neurological dysfunction | 954 | Blood | End-CPB and peak in ICU | NR | Cerebral complications | 9.9% had the outcome. Peak in the ICU was higher in those with the outcome. End-CPB lactate was associated with the outcome in multivariable analysis |
| Slottosch  2013 32 | 1 | Jan. 2006 – Dec. 2010 | Retrospective | ECMO after cardiac surgery for shock | Central thoracic ECMO, ECMO for other reasons | 77 | NR | 24 hours after ECMO | NR | Death | Higher in non-survivors. Remained in multivariable analysis |
| Lindsay  2013 33 | 1 | Jan. 2008 – Aug. 2008 | Retrospective | CABG, valve surgery, or combined | < 2 lactate measurements within 12 hours after surgery | 1,291 | Arterial. Predicted lactate clearance time | First 12 hours post-operatively | NR | LOS, complications, mortality | Associated with the outcomes. Remained in multivariable analysis |
| Groesdonk  2013 34 | 1 | Jan. 2010 – Mar. 2011 | Prospective | Elective cardiac surgery with CPB | - | 865 | Serum | NR | > 5 | Non-occlusive  mesenteric ischemia | 9% had the outcome. More patients with the outcome had high lactate. Remained in multivariable analysis |
| Lopez-Delgado  2013 35 | 1 | Jan. 2004 – Jan. 2009 | Prospective | Cardiac surgery and liver cirrhosis | - | 58 | Arterial | ICU admission and 24 hour after | NR | Mortality | 24 hours after was higher in non-survivors, no difference on admission. Did not remain on multivariable analysis |
| Hajjar  2013 36 | 1 | Feb. 2009 – Feb. 2010 | Prospective | Elective cardiac surgery with CPB | Multiple including a number of pre-existing conditions and types of surgery | 502 | Blood | During surgery, ICU arrival, and 6 and 12 hours after | > 3 at 6 hours, > 2 at 24 hours | Complications | Higher lactates in those with complications. Lactate at 6 hours remained associated in multivariable analysis. AUC: 0.72 at 6 hours, AUC: 0.78 at 24 hours |
| Wang  2013 37 | 1 | Jan. 2005 – Dec. 2011 | Retrospective | VA-ECMO after valve surgery | - | 87 | NR | NR | > 12 | Mortality | Peak lactate higher in non-survivors. High lactate associated with mortality in multivariable analysis |
| Jabbari  2013 38 | 1 | Aug. – Sept. 2012 | Prospective | Routine cardiac surgery | Surgical complication | 15 | Serum | During (every 30 min) and after (every 6 hours) surgery | NR | Complications | Higher lactate levels in those with complication |
| Laine  2013 39 | 1 | Sept. 2010 – Dec. 2011 | Retrospective | Cardiac surgery with CPB | Combined ScvO2 < 70% and  lactate > 2 | 526 | Arterial | Arrival at ICU | > 2/> 4 | LOS, complications, mortality | High lactate associated with LOS and complications but not significantly with mortality. Association with hospital LOS and major complications remained in multivariable analysis |
| Lopez-Delgado  2013 40 | 1 | Jan. 2004 – Jul. 2009 | Retrospective | Cardiac surgery | Heart transplant, pre-operative renal disease and dialysis | 2940 | Arterial | ICU admission and 24 hours after | NR | Acute kidney injury | Higher lactates in those with acute kidney injury. 24 hours lactate remained associated in multivariable analysis |
| Tamayo  2013 41,42 | 1 | Jan. 2009 – Jan. 2011 | Prospective | Cardiac valve and/  or coronary surgery with CPB | Heart transplant | 909 | Blood | ICU admission | NR | Mortality | Lactate higher in non-survivors. Remained in multiple variable analysis |
| Badreldin  2013 43 | 1 | Jan. 2007 – Dec. 2009 | Prospective | Cardiac surgery | - | 4,054 | Arterial | Highest in first 24 hours after surgery | Multiple cut-offs: 1.8, 6.0, 9.4, and 13.4 | ICU mortality | Increasing mortality with each category. AUC: 0.88. Addition of lactate improved other scoring systems |
| Park  2014 44 | 1 | May 2005 – Dec. 2011 | Retrospective | Extra-corporeal life support after cardiac surgery | - | 94 | Serum | Before extra-corporeal life support | >7.9 | Mortality | Higher lactate levels in those that died. Remained in multivariable analysis. Sens. 63%, spec. 68%, AUC: 0.73 for cut-off |
| Park  2014 45 | 1 | May 2005 – Dec. 2012 | Retrospective | Extra-corporeal life support after cardiac surgery | - | 115 | Arterial | Every 2-3 hours | Various | Complications | Higher lactates in those with complications at all time points. Remained in multivariable analysis |
| Ranucci  2015 46 | 2 | Jan. 2010 – Dec. 2013 | Retrospective | Cardiac surgery | Heart transplant | 4251 | Arterial | Arrival to ICU | > 4 | Post-operative bleeding | Associated with the outcome. Remained in multivariable analysis |
| Lopez-Delgado  2015 47 | 1 | Jan. 2004 – Jan. 2009 | Prospective | Cardiac surgery and liver cirrhosis | - | 51 | Arterial | Admission to ICU and 24 hours after |  | Long-term mortality | 24 hour lactate associated with the outcome. At admission not. Did not remain in multivariable analysis |
| Papadopoulos 2015 48 | 1 | Dec. 2001 – Jun. 2013 | Prospective | Extra-corporeal life support after cardiac surgery | - | 360 | Serum | NR | > 120 mg/dL | Failure to wean, mortality | Associated with the outcome (unclear which) |
| Rubino  2015 49 | 1 | NR | Prospective | Cardiac surgery on  CPB with aortic cross-clamping. | Multiple including heart transplant, congenital disease and pre-existing renal failure | 187 | Arterial | Peak during CPB and the first 3 days | > 3 | High lactate, complications, mortality | Included in score that was associated with most of the outcomes |
| Li  2015 50 | 1 | Jan. 2011 – Dec. 2012 | Retrospective | VA-ECMO after cardiac surgery | - | 123 | Arterial, serum | Average and lactate clearance first 6 and 12 hours | NR | Complications, weaning | Both mean and clearance associated with mortality. Remained in multivariable analysis. Only 12 hour associated with weaning |
| Zhang  2015 51 | 1 | Jul. 2012 – Jan. 2014 | Prospective | Cardiac surgery with CPB | Severe complication, prior dialysis | 117 | Serum | 4-hour intervals for the first 24 hours. Lactate load | 4.4 | Acute kidney injury | Higher in those with the outcome. Remained in multivariable analysis. Initial lactate AUC: 0.63. Sens.: 41%, spec.: 87% for cut-off. Increasing AUC at later time points |
| Saxena  2015 52 | 1 | Jan. 2003 – Jan. 2013 | Retrospective | ECMO after cardiac surgery.  > 70 years | - | 45 | NR | Mean and max post-operative | NR | Mortality | Both higher in those that died |
| Zacharias  2015 53 | 1 | Jul. 2009 – Aug. 2010 | Prospective | Cardiac surgery with CPB | - | 85 | Plasma | 24 hours after surgery | NR | Acute kidney injury | Higher in those with the outcome |
| Hsu  2015 54 | 1 | Jun. 2006 – May 2013 | Retrospective | Heart transplant and lactate > 15 | - | 12 | Arterial | After surgery | > 15 | Mortality | Return to lactate < 4 associated with time on mechanical ventilation. |
| Lopez-Delgado 2015 55 | 1 | Jan. 2004 – Dec. 2009 | Prospective | Cardiac surgery | Off-pump surgery, heart transplant and prior liver dysfunction | 2935 | Arterial | ICU admission and 6, 12, and 24 hours later | > 3 | Complication, LOS, in-hospital and long-term mortality | Associated with the outcomes. Higher at all time points in non-survivors (short- and long-term). AUC highest at 24 hours. Changes in lactate similar between groups (no statistics provided) |
| Youssefi  2015 56 | 1 | Oct. 2011 – Oct. 2013 | Prospective | Cardiac surgery with post-operative “fast track” | Multiple | 451 | NR | Arrival to ICU | NR | Successful fast track management | Higher lactate in those that failed. Did not remain in multivariable analysis |
| Andersen  2015 57 | 1 | 2002 - 2014 | Retrospective | CABG or valve surgery | No lactate value, off-pump surgery | 1,208 | NR | Within 3 hours of skin closure | > 2  > 4 | LOS, complications, mortality | Associated with the outcomes. Remained in multivariable analysis (mortality not analyzed) |
| Ranucci  2015 58 | 1 | Jan. 2010 – Dec. 2013 | Retrospective | Cardiac surgery | Transplant, off-pump | 3,851 | Blood | Arrival in ICU | > 2.1  > 6.0 | Complication, mortality | Associated with the outcomes. No multivariable analyses. |
| Jorge-Monjas 2016 59 | 2 | Jan. 2012 – Jan. 2014 and Mar. 2014 – Mar. 2015 | Prospective | CABG and/or valve  surgery with CPB | - | 1551 | NR | During surgery and at arrival to ICU | NR | Acute kidney injury | No difference in lactate during the surgery. Higher in those with the outcome at ICU arrival. Remained in multivariable analysis. Included in score. |
| Mothes 2016 60 | 1 | Jan. 2005 – Dec. 2012 | Retrospective case-control | Cardiac surgery with CPB | - | 433 | NR | Day 0 and 1 post-operatively | > 3 | Acute mesenteric ischemia (laparotomy) | Higher in cases. Remained in multivariable analysis. |

a The table provides a brief summarized overview of the different studies. The summary focuses on the reporting and analysis of lactate in the included studies which was often not the primary goal of the study. No formal assessment of the quality of the included studies was performed and the summary results should therefore be interpreted carefully. This table is not meant to be a comprehensive description of the included studies.

b Abbreviations: NR: not reported, CPB: cardiopulmonary bypass, LOS: length of stay, CHF: congestive heart failure, LVEF: left-ventricular ejection fraction, IABP: intraaortic balloon pump, PPV: positive predictive value, NPV: negative predictive value, CABG: coronary artery bypass grafting, AUC: area under the receiver operating characteristics curve, ICU: intensive care unit, sens.: sensitivity, spec: specificity, ECMO: extracorporeal membrane oxygenation, BMI: body mass index, EF: ejection fraction, DO2: Oxygen delivery, Max.: maximum RRT: renal replacement therapy, AF: atrial fibrillation, NYHA: New York Heart Association, EuroSCORE: European system for cardiac operative risk evaluation, VA-ECMO: veno-arterial extracorporeal membrane oxygenation, ScvO2: Central venous oxygen saturation

c All studies were observational cohort studies unless otherwise noted

d All lactates are reported in mmol/L unless otherwise noted

**REFERENCES**

1. Schutz A, Eichinger W, Breuer M, Gansera B, Kemkes BM: Acute mesenteric ischemia after open heart surgery. Angiology 1998; 49: 267-73

2. Demers P, Elkouri S, Martineau R, Couturier A, Cartier R: Outcome with high blood lactate levels during cardiopulmonary bypass in adult cardiac operation. Ann Thorac Surg 2000; 70: 2082-6

3. Davies AR, Bellomo R, Raman JS, Gutteridge GA, Buxton BF: High lactate predicts the failure of intraaortic balloon pumping after cardiac surgery. Ann Thorac Surg 2001; 71: 1415-20

4. Rao V, Ivanov J, Weisel RD, Cohen G, Borger MA, Mickle DA: Lactate release during reperfusion predicts low cardiac output syndrome after coronary bypass surgery. Ann Thorac Surg 2001; 71: 1925-30

5. Byhahn C, Strouhal U, Martens S, Mierdl S, Kessler P, Westphal K: Incidence of gastrointestinal complications in cardiopulmonary bypass patients. World J Surg 2001; 25: 1140-4

6. Klotz S, Vestring T, Rotker J, Schmidt C, Scheld HH, Schmid C: Diagnosis and treatment of nonocclusive mesenteric ischemia after open heart surgery. Ann Thorac Surg 2001; 72: 1583-6

7. Takami Y, Ina H: Significance of the initial arterial lactate level and transpulmonary arteriovenous lactate difference after open-heart surgery. Surg Today 2002; 32: 207-12

8. Dixon B, Santamaria JD, Campbell DJ: Plasminogen activator inhibitor activity is associated with raised lactate levels after cardiac surgery with cardiopulmonary bypass. Crit Care Med 2003; 31: 1053-9

9. Maillet JM, Le Besnerais P, Cantoni M, Nataf P, Ruffenach A, Lessana A, Brodaty D: Frequency, risk factors, and outcome of hyperlactatemia after cardiac surgery. Chest 2003; 123: 1361-6

10. Toraman F, Evrenkaya S, Yuce M, Aksoy N, Karabulut H, Bozkulak Y, Alhan C: Lactic acidosis after cardiac surgery is associated with adverse outcome. Heart Surg Forum 2004; 7: E155-9

11. Huwer H, Winning J, Straub U, Isringhaus H, Kalweit G: Clinically diagnosed nonocclusive mesenteric ischemia after cardiopulmonary bypass: retrospective study. Vascular 2004; 12: 114-20

12. Shinde SB, Golam KK, Kumar P, Patil ND: Blood lactate levels during cardiopulmonary bypass for valvular heart surgery. Ann Card Anaesth 2005; 8: 39-44

13. Heringlake M, Bahlmann L, Misfeld M, Poeling J, Leptien A, Kraatz E, Klaus S: High myocardial lactate concentration is associated with poor myocardial function prior to cardiopulmonary bypass. Minerva Anestesiol 2005; 71: 775-83

14. Hekmat K, Kroener A, Stuetzer H, Schwinger RH, Kampe S, Bennink GB, Mehlhorn U: Daily assessment of organ dysfunction and survival in intensive care unit cardiac surgical patients. Ann Thorac Surg 2005; 79: 1555-62

15. Zhang R, Kofidis T, Kamiya H, Shrestha M, Tessmann R, Haverich A, Klima U: Creatine kinase isoenzyme MB relative index as predictor of mortality on extracorporeal membrane oxygenation support for postcardiotomy cardiogenic shock in adult patients. Eur J Cardiothorac Surg 2006; 30: 617-20

16. Svenmarker S, Haggmark S, Ostman M: What is a normal lactate level during cardiopulmonary bypass? Scand Cardiovasc J 2006; 40: 305-11

17. Ranucci M, De Toffol B, Isgro G, Romitti F, Conti D, Vicentini M: Hyperlactatemia during cardiopulmonary bypass: determinants and impact on postoperative outcome. Crit Care 2006; 10: R167

18. Oshima K, Kunimoto F, Takahashi T, Mohara J, Takeyoshi I, Hinohara H, Hayashi Y, Tajima Y, Kuwano H: Factors for successful weaning from a percutaneous cardiopulmonary support system (PCPS) in patients with low cardiac output syndrome after cardiovascular surgery. Int Heart J 2007; 48: 743-54

19. Abarbanell GL, Goldberg CS, Devaney EJ, Ohye RG, Bove EL, Charpie JR: Early surgical morbidity and mortality in adults with congenital heart disease: the University of Michigan experience. Congenit Heart Dis 2008; 3: 82-9

20. Hauer D, Kilger E, Kaufmann I, Kreth S, Beiras-Fernandez A, Briegel J, Schelling G, Schmidt M, Weis F: Risk and outcome analysis of renal replacement therapies in patients after cardiac surgery with pre-operatively normal renal function. Anaesthesia 2009; 64: 615-9

21. Boeken U, Feindt P, Litmathe J, Kurt M, Gams E: Intraaortic balloon pumping in patients with right ventricular insufficiency after cardiac surgery: parameters to predict failure of IABP Support. Thorac Cardiovasc Surg 2009; 57: 324-8

22. Gasparovic H, Burcar I, Kopjar T, Vojkovic J, Gabelica R, Biocina B, Jelic I: NT-pro-BNP, but not C-reactive protein, is predictive of atrial fibrillation in patients undergoing coronary artery bypass surgery. Eur J Cardiothorac Surg 2010; 37: 100-5

23. Nogueira PM, Mendonca-Filho HT, Campos LA, Gomes RV, Felipe AR, Fernandes MA, Villela-Nogueira CA, Rocco JR: Central venous saturation: a prognostic tool in cardiac surgery patients. J Intensive Care Med 2010; 25: 111-6

24. Rastan AJ, Dege A, Mohr M, Doll N, Falk V, Walther T, Mohr FW: Early and late outcomes of 517 consecutive adult patients treated with extracorporeal membrane oxygenation for refractory postcardiotomy cardiogenic shock. J Thorac Cardiovasc Surg 2010; 139: 302-11, 311 e1

25. Ranucci M, Ballotta A, Castelvecchio S, Baryshnikova E, Brozzi S, Boncilli A, Surgical, Clinical Outcome Research G: Intensive care unit admission parameters improve the accuracy of operative mortality predictive models in cardiac surgery. PLoS One 2010; 5: e13551

26. Kapoor P, Mandal B, Chowdhury U, Singh S, Kiran U: Changes in myocardial lactate, pyruvate and lactate-pyruvate ratio during cardiopulmonary bypass for elective adult cardiac surgery: Early indicator of morbidity. J Anaesthesiol Clin Pharmacol 2011; 27: 225-32

27. Noval-Padillo JA, Serra-Gomez C, Gomez-Sosa L, Hinojosa-Perez R, Huici-Moreno MJ, Adsuar A, Herruzo-Aviles A, Lopez-Romero JL, Leon-Justel A, Guerrero-Montavez JM: Changes of lactate levels during cardiopulmonary bypass in patients undergoing cardiac transplantation: possible early marker of morbidity and mortality. Transplant Proc 2011; 43: 2249-50

28. Canadyova J, Zmeko D, Mokracek A: Re-exploration for bleeding or tamponade after cardiac operation. Interact Cardiovasc Thorac Surg 2012; 14: 704-7

29. Hu BY, Laine GA, Wang S, Solis RT: Combined central venous oxygen saturation and lactate as markers of occult hypoperfusion and outcome following cardiac surgery. J Cardiothorac Vasc Anesth 2012; 26: 52-7

30. Kogan A, Preisman S, Bar A, Sternik L, Lavee J, Malachy A, Spiegelstein D, Berkenstadt H, Raanani E: The impact of hyperlactatemia on postoperative outcome after adult cardiac surgery. J Anesth 2012; 26: 174-8

31. Nicolini F, Maestri F, Fragnito C, Belli L, Malchiodi L, Venazzi A, Agostinelli A, Gallingani A, De Carlo L, Gherli T: Early neurological injury after cardiac surgery: insights from a single centre prospective study. Acta Biomed 2013; 84: 44-52

32. Slottosch I, Liakopoulos O, Kuhn E, Deppe AC, Scherner M, Madershahian N, Choi YH, Wahlers T: Outcomes after peripheral extracorporeal membrane oxygenation therapy for postcardiotomy cardiogenic shock: a single-center experience. J Surg Res 2013; 181: e47-55

33. Lindsay AJ, Xu M, Sessler DI, Blackstone EH, Bashour CA: Lactate clearance time and concentration linked to morbidity and death in cardiac surgical patients. Ann Thorac Surg 2013; 95: 486-92

34. Groesdonk HV, Klingele M, Schlempp S, Bomberg H, Schmied W, Minko P, Schafers HJ: Risk factors for nonocclusive mesenteric ischemia after elective cardiac surgery. J Thorac Cardiovasc Surg 2013; 145: 1603-10

35. Lopez-Delgado JC, Esteve F, Javierre C, Perez X, Torrado H, Carrio ML, Rodriguez-Castro D, Farrero E, Ventura JL: Short-term independent mortality risk factors in patients with cirrhosis undergoing cardiac surgery. Interact Cardiovasc Thorac Surg 2013; 16: 332-8

36. Hajjar LA, Almeida JP, Fukushima JT, Rhodes A, Vincent JL, Osawa EA, Galas FR: High lactate levels are predictors of major complications after cardiac surgery. J Thorac Cardiovasc Surg 2013; 146: 455-60

37. Wang JG, Han J, Jia YX, Zeng W, Hou XT, Meng X: Outcome of veno-arterial extracorporeal membrane oxygenation for patients undergoing valvular surgery. PLoS One 2013; 8: e63924

38. Jabbari A, Banihashem N, Alijanpour E, Vafaey HR, Alereza H, Rabiee SM: Serum lactate as a prognostic factor in coronary artery bypass graft operation by on pump method. Caspian J Intern Med 2013; 4: 662-6

39. Laine GA, Hu BY, Wang S, Thomas Solis R, Reul GJ, Jr.: Isolated high lactate or low central venous oxygen saturation after cardiac surgery and association with outcome. J Cardiothorac Vasc Anesth 2013; 27: 1271-6

40. Lopez-Delgado JC, Esteve F, Torrado H, Rodriguez-Castro D, Carrio ML, Farrero E, Javierre C, Ventura JL, Manez R: Influence of acute kidney injury on short- and long-term outcomes in patients undergoing cardiac surgery: risk factors and prognostic value of a modified RIFLE classification. Crit Care 2013; 17: R293

41. Tamayo E, Fierro I, Bustamante-Munguira J, Heredia-Rodriguez M, Jorge-Monjas P, Maroto L, Gomez-Sanchez E, Bermejo-Martin F, Alvarez F, Gomez-Herreras J: Development of the Post Cardiac Surgery (POCAS) prognostic score. Crit Care 2013; 17: R209

42. Tamayo E, Fierro I, Bustamante-Munguira J, Heredia-Rodriguez M, Jorge-Monjas P, Maroto L, Gomez-Sanchez E, Bermejo-Martin FJ, Alvarez FJ, Gomez-Herreras JI: Erratum to: Development of the Post Cardiac Surgery (POCAS) prognostic score. Crit Care 2015; 19: 395

43. Badreldin AM, Doerr F, Elsobky S, Brehm BR, Abul-dahab M, Lehmann T, Bayer O, Wahlers T, Hekmat K: Mortality prediction after cardiac surgery: blood lactate is indispensible. Thorac Cardiovasc Surg 2013; 61: 708-17

44. Park SJ, Kim JB, Jung SH, Choo SJ, Chung CH, Lee JW: Outcomes of extracorporeal life support for low cardiac output syndrome after major cardiac surgery. J Thorac Cardiovasc Surg 2014; 147: 283-9

45. Park SJ, Kim SP, Kim JB, Jung SH, Choo SJ, Chung CH, Lee JW: Blood lactate level during extracorporeal life support as a surrogate marker for survival. J Thorac Cardiovasc Surg 2014; 148: 714-20

46. Ranucci M, Baryshnikova E, Simeone F, Ranucci M, Scolletta S: Moderate-degree acidosis is an independent determinant of postoperative bleeding in cardiac surgery. Minerva Anestesiol 2015; 81: 885-93

47. Lopez-Delgado JC, Esteve F, Javierre C, Torrado H, Carrio ML, Rodriguez-Castro D, Farrero E, Lluis Ventura J, Manez R: Predictors of long-term mortality in patients with cirrhosis undergoing cardiac surgery. J Cardiovasc Surg (Torino) 2015; 56: 647-54

48. Papadopoulos N, Marinos S, El-Sayed Ahmad A, Keller H, Meybohm P, Zacharowski K, Moritz A, Zierer A: Risk factors associated with adverse outcome following extracorporeal life support: analysis from 360 consecutive patients. Perfusion 2015; 30: 284-90

49. Rubino AS, Torrisi S, Milazzo I, Fattouch K, Busa R, Mariani C, D'Aleo S, Giammona D, Sferrazzo C, Mignosa C: Designing a new scoring system (QualyP Score) correlating the management of cardiopulmonary bypass to postoperative outcomes. Perfusion 2015; 30: 448-56

50. Li CL, Wang H, Jia M, Ma N, Meng X, Hou XT: The early dynamic behavior of lactate is linked to mortality in postcardiotomy patients with extracorporeal membrane oxygenation support: A retrospective observational study. J Thorac Cardiovasc Surg 2015; 149: 1445-50

51. Zhang Z, Ni H: Normalized lactate load is associated with development of acute kidney injury in patients who underwent cardiopulmonary bypass surgery. PLoS One 2015; 10: e0120466

52. Saxena P, Neal J, Joyce LD, Greason KL, Schaff HV, Guru P, Shi WY, Burkhart H, Li Z, Oliver WC, Pike RB, Haile DT, Schears GJ: Extracorporeal Membrane Oxygenation Support in Postcardiotomy Elderly Patients: The Mayo Clinic Experience. Ann Thorac Surg 2015; 99: 2053-60

53. Zacharias HU, Hochrein J, Vogl FC, Schley G, Mayer F, Jeleazcov C, Eckardt KU, Willam C, Oefner PJ, Gronwald W: Identification of Plasma Metabolites Prognostic of Acute Kidney Injury after Cardiac Surgery with Cardiopulmonary Bypass. J Proteome Res 2015; 14: 2897-905

54. Hsu YC, Hsu CH, Huang GS, Lu CC, Wu ZF, Tsai YT, Lin CY, Lin YC, Tsai CS, Lin TC: Extreme Hyperlactatemia After Heart Transplantation: One Center's Experience. Transplant Proc 2015; 47: 1945-8

55. Lopez-Delgado JC, Esteve F, Javierre C, Torrado H, Rodriguez-Castro D, Carrio ML, Farrero E, Skaltsa K, Manez R, Ventura JL: Evaluation of Serial Arterial Lactate Levels as a Predictor of Hospital and Long-Term Mortality in Patients After Cardiac Surgery. J Cardiothorac Vasc Anesth 2015; 29: 1441-53

56. Youssefi P, Timbrell D, Valencia O, Gregory P, Vlachou C, Jahangiri M, Edsell M: Predictors of Failure in Fast-Track Cardiac Surgery. J Cardiothorac Vasc Anesth 2015; 29: 1466-71

57. Andersen LW, Holmberg MJ, Doherty M, Khabbaz K, Lerner A, Berg KM, Donnino MW: Postoperative Lactate Levels and Hospital Length of Stay After Cardiac Surgery. J Cardiothorac Vasc Anesth 2015; 29: 1454-60

58. Ranucci M, Carboni G, Cotza M, Bianchi P, Di Dedda U, Aloisio T, Surgical, Clinical Outcome Research G: Hemodilution on cardiopulmonary bypass as a determinant of early postoperative hyperlactatemia. PLoS One 2015; 10: e0126939

59. Jorge-Monjas P, Bustamante-Munguira J, Lorenzo M, Heredia-Rodriguez M, Fierro I, Gomez-Sanchez E, Hernandez A, Alvarez FJ, Bermejo-Martin JF, Gomez-Pesquera E, Gomez-Herreras JI, Tamayo E: Predicting cardiac surgery-associated acute kidney injury: The CRATE score. J Crit Care 2016; 31: 130-8

60. Mothes H, Koeppen J, Bayer O, Richter M, Kabisch B, Schwarzkopf D, Hein HA, Zanow J, Doenst T, Settmacher U: Acute mesenteric ischemia following cardiovascular surgery - A nested case-control study. Int J Surg 2016; 26: 79-85