DO2:
Is it ALL That It's Cracked up to Be?

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Disclosures:

- I have no disclosures

What is DO2 and why are we interested?

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- Delivery of Oxygen or DO2 is the amount of oxygen delivered to the body's tissues each minute. Normal DO2 is 600ml/min/m2 and normal VO2, volume of oxygen consumed is 120ml/min/m2. Or a 5:1 ratio of delivery:consumption
- Oxygen Delivery(DO2) = Cardiac output X oxygen content
- When DO2 is impaired more oxygen is extracted leading to a lower venous oxygen content.
- When Delivery of oxygen(DO2)/Volume oxygen consumed(VO2) nears 2:1, anaerobic metabolism will occur with resultant lactic acidosis, multi-organ- failure, and cardiovascular collapse.
- This is human physiology and clinicians manage this ratio in critical care settings.
- Does it make sense to monitor DO2 on cardio-pulmonary bypass?

History of DO2 on CPB

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Ranucci 2005 Oxygen Delivery during cardiopulmonary bypass and acute renal failure after coronary operations

- Established the critical value at 272ml/min/m2 as the lowest oxygen delivery as the best predictor for acute renal failure and serum creatinine level rise post op in adult patients.

deSomer 2011 O2 delivery and CO2 production during Cardiopulmonary Bypass as determinants of AKI for goal directed perfusion management operations

- Used a Nadir DO2 level less than 262ml/min/m2 and Nadir DO2/VCO2 ratio as independently associated predictors of AKI
- Both variables were predictive of AKI, with DO2 being the most accurate predictor of AKI stage 2 postoperative status

DO2 and Outcome Variables

What Clinical variables are reported in the literature to be improved with targeted DO2 levels on CPB?

- Acute Kidney Injury(AKI) is reported in numerous Adult and Pediatric studies involving the measurement of DO2 on CPB, 40% AKI rate in adults, 52% in infants and 64% in neonate populations
    - 225-272ml/min/m2 has been reported as the critical low threshold of DO2
- Hospital Length of Stay(LOS) has been shown to be decreased in studies comparing Nadir DO2 levels. High DO2 pt group had lowest LOS
- Prolonged Ventilation Times are associated with DO2 levels below 280ml/min/m2 and improved when comparing DO2 levels in the literature
- Lactate clearance below 3.0mmol/L associated with positive association of increased DO2 on CPB
- Decreased glucose levels associated with positive effects of increased DO2
- STS data correlation to DO2 may be associated with morbidity/mortality rates
    - DO2 levels in the targeted 280-300ml/min/m2 and cardiac index below 2.2l/min
    - Hemoglobin less than baseline and lower Blood Pressure

Where do we go from here?

DO2 as a component of Goal Directed Perfusion

- Goal Directed Perfusion(GDP) refers to individualized goal-directed therapy using comprehensive monitoring and optimizing the delivery of oxygen and uptake of oxygen during cardiopulmonary bypass
- Delivery of Oxygen is a multi-factorial variable representing a target value derived from arterial pump flow and oxygen content.
- DO2 is a measurable variable in a GDP model
- Reagor presented a cardiac index of 3.0l/min showed improved outcomes vs lower index of 2.4l/min and transfusing RBC to increase DO2 levels
  - High arterial pump flow with lower accepted Hgb, vs Lower arterial pump flow and higher Hgb
  - optimization of oxygen delivery via higher flow index rather than increased hematocrit is more comprehensive in reflecting tissue oxygen supply than the independent parameters.
- No agreed upon target DO2 reported
  - Adult range 272-300 ml/min/m2 supports improved risk of minimizing AKI
  - Pediatric levels have been reported to range from 300-353ml/min/m2, 400ml/min/m2 has been reported

Where do we go from here?

Rannucci 2024 The multifactorial dynamic perfusion index: A predictive tool of cardiac surgery associated acute kidney injury

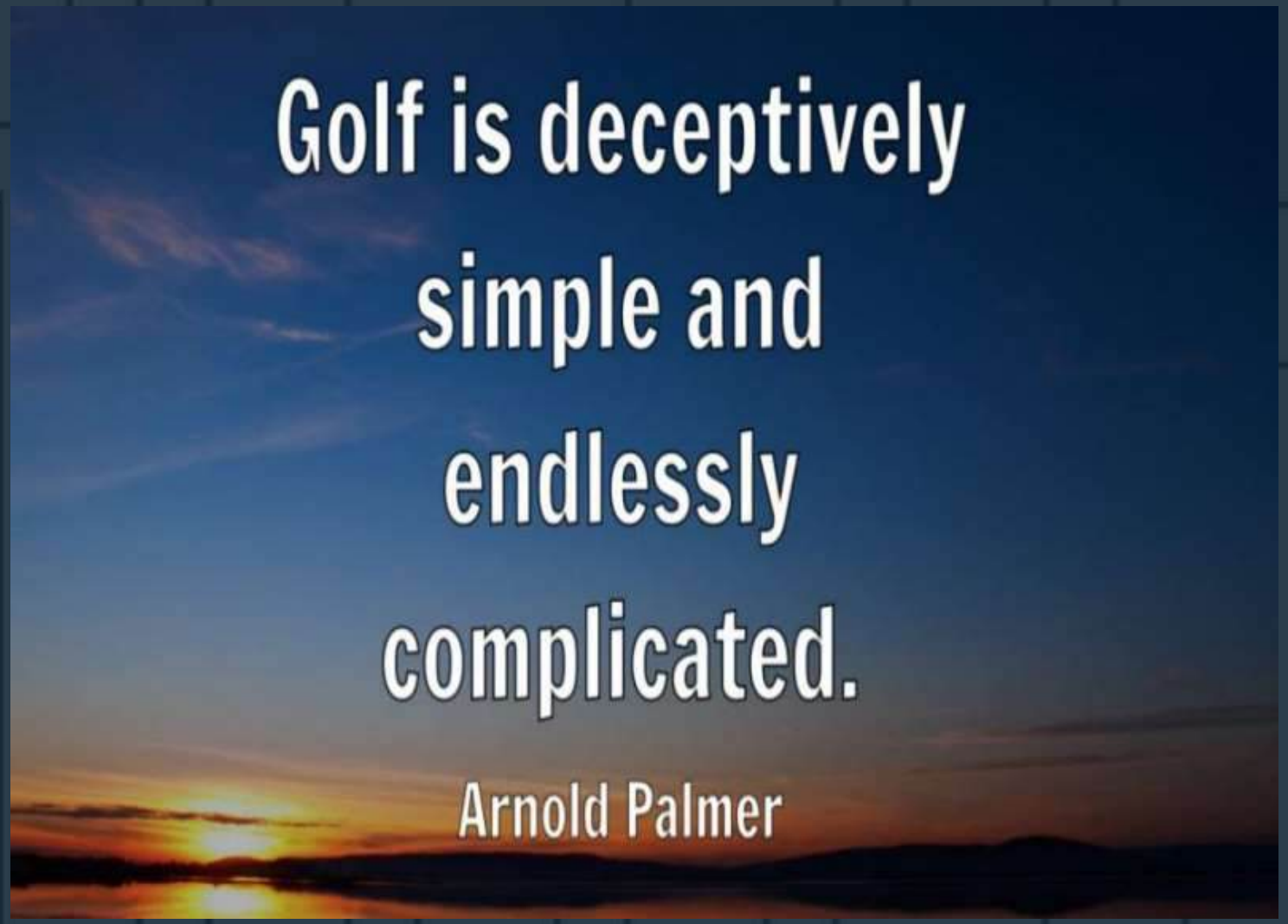
- The MDPI has better predictive ability than the existing static risk models and is promising tool to integrate different factors into an advanced concept of goal directed perfusion.

In Summary

In Summary DO2 IS ALL it's cracked up to be

- DO2 is one of the most measurable and adjustable variables to help clinicians reduce deleterious effects of hypoperfusion relating to AKI and other measured quality variables.
- No consensus is determined for a target DO2 number, but a consensus range is 275-350ml/min/m2, lower values considered the critical threshold.
- 340ml/min/m2 in pediatrics was determined to maintain aerobic metabolism and reduce AKI in separate studies.
- Studies support time under a target DO2 as well as the absolute DO2 number have role in outcomes
- Temperature correlations not strongly studied to support that critical DO2 levels may be decreased at temperatures below 32 degrees. Many studies only include procedures above 32 degrees.
- Cardiac Index flow has an important influence in Delivery of Oxygen target value
- Incorporating Goal directed Perfusion variables with DO2 measurement may provide best results
- Multifactorial dynamic perfusion index model may provide future considerations for DO2 and quality improvement studies.

Thank You


Golf is deceptively
simple and
endlessly
complicated.
Arnold Palmer

References

1. Magruder JT, KG, Haddle J, Desai ND, Szeto WY, Acker MA; Penn Perfusion Team Working Group. Correlating oxygen delivery on cardiopulmonary bypass wiWeiss SJ, DeAngelis th Society of Thoracic Surgeons outcomes following cardiac surgery. J Thorac Cardiovasc Surg. 2022 Sep;164(3):997-1007. doi: 10.1016/j.jtcvs.2020.12.008. Epub 2020 Dec 19. PMID: 33485654.

2. Dreher M, Min J, Mavroudis C, Ryba D, Ostapenko S, Melchior R, Rosenthal T, Nuri M, Blinder J. Indexed oxygen delivery during pediatric cardiopulmonary bypass is a modifiable risk factor for postoperative acute kidney injury. J Extra Corpor Technol. 2023 Sep;55(3):112-120. doi: 10.1051/ject/2023029. Epub 2023 Sep 8. PMID: 37682209; PMCID: PMC10487348.

3. de Somer F, Mulholland JW, Bryan MR, Aloisio T, Van Nooten GJ, Ranucci M. O2 delivery and CO2 production during cardiopulmonary bypass as determinants of acute kidney injury: time for a goal-directed perfusion management? Crit Care. 2011 Aug 10;15(4):R192. doi: 10.1186/cc10349. PMID: 21831302; PMCID: PMC3387634.

4. Ranucci M, Romitti F, Isgrò G, Cotza M, Brozzi S, Boncilli A, Ditta A. Oxygen delivery during cardiopulmonary bypass and acute renal failure after coronary operations. Ann Thorac Surg. 2005 Dec;80(6):2213-20. doi: 10.1016/j.athoracsur.2005.05.069. PMID: 16305874.

5. Bojan M, Gioia E, Di Corte F, Berkia I, Tourneur T, Tourneur L, De Somer F. Lower limit of adequate oxygen delivery for the maintenance of aerobic metabolism during cardiopulmonary bypass in neonates. Br J Anaesth. 2020 Apr;124(4):395-402. doi: 10.1016/j.bja.2019.12.034. Epub 2020 Feb 5. PMID: 32035629.

6. Ranucci M, Carboni G, Cotza M, Bianchi P, Di Dedda U, Aloisio T; Surgical and Clinical Outcome Research (SCORE) Group. Hemodilution on cardiopulmonary bypass as a determinant of early postoperative hyperlactatemia. PLoS One. 2015 May 18;10(5):e0126939. doi: 10.1371/journal.pone.0126939. PMID: 25992896; PMCID: PMC4436314.

7. Reagor JA, Clingan S, Gao Z, Morales DLS, Tweddell JS, Bryant R, Young W, Cavanaugh J, Cooper DS. Higher Flow on Cardiopulmonary Bypass in Pediatrics Is Associated With a Lower Incidence of Acute Kidney Injury. Semin Thorac Cardiovasc Surg. 2020 Winter;32(4):1015-1020. doi: 10.1053/j.semtcvs.2019.08.007. Epub 2019 Aug 16. PMID: 31425753.

8. Mukaida H, Matsushita S, Minami Y, Sato G, Usuba M, Kondo R, Asai T, Amano A. Risk factors for postoperative delirium on oxygen delivery-guided perfusion. J Cardiothorac Surg. 2022 Aug 20;17(1):193. doi: 10.1186/s13019-022-01938-z. PMID: 35987682; PMCID: PMC9392930.

9. Mukaida H, Matsushita S, Kuwaki K, Inotani T, Minami Y, Saigusa A, Amano A. Time-dose response of oxygen delivery during cardiopulmonary bypass predicts acute kidney injury. J Thorac Cardiovasc Surg. 2019 Aug;158(2):492-499. doi: 10.1016/j.jtcvs.2018.10.148. Epub 2018 Nov 16. PMID: 30578056.

10. Newland RF, Baker RA, Woodman RJ, Barnes MB, Willcox TW; Australian and New Zealand Collaborative Perfusion Registry. Predictive Capacity of Oxygen Delivery During Cardiopulmonary Bypass on Acute Kidney Injury. Ann Thorac Surg. 2019 Dec;108(6):1807-1814. doi: 10.1016/j.athoracsur.2019.04.115. Epub 2019 Jun 22. PMID: 31238029.

11. Salenger R, Fonner CE, Kampert C, Rea A, Evans C, Arora RC. Trial of Oxygen Delivery on Cardiopulmonary Bypass and Major Clinical Outcomes. Ann Thorac Surg Short Rep. 2024 Jun 7;2(4):855-859. doi: 10.1016/j.atssr.2024.05.012. PMID: 39790595; PMCID: PMC11708650.

12. Condello I, Santarpino G, Nasso G, Moscarelli M, Fiore F, Speziale G. Associations between oxygen delivery and cardiac index with hyperlactatemia during cardiopulmonary bypass. JTCVS Tech. 2020 Apr 13;2:92-99. doi: 10.1016/j.xjtc.2020.04.001. PMID: 34317766; PMCID: PMC8299069

13. Clingan S, Reagor J, Lombardi J. Retrospective analysis of cardiac index and lactate production on cardiopulmonary bypass for a congenital cardiac patient population. Perfusion. 2019 Apr;34(3):231-235. doi: 10.1177/0267659118813076. Epub 2018 Nov 14. PMID: 30428765.

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DO2 and Associated Clinical Outcomes

Today 600+ articles on a Pubmed search on the topic Delivery of Oxygen and Cardiopulmonary Bypass exist.

Numerous studies address the benefits of measuring and targeting DO2 critical thresholds for decreasing risk of AKI and other measurable Variables of patient care

Pediatric studies show higher required target levels compared to adult

- Cyanotic disease
- Increased Metabolic rates
- Time under the DO2 threshold, or area under the curve studied in numerous articles reflecting time vs an absolute low value may affect AKI not just the Nadir DO2 on Cardio-pulmonary bypass.