İNTRAOPERATİF ANEMİYE MAKSİMUM TOLERANSIN SAĞLANMASINDA SEREBRAL MONİTÖRİZASYONUN YERİ

PROF. DR. FEVZİ TORAMAN

ACIBADEM ÜNİVERSİTESİ

GKDA 2017 İstanbul

Konu Başlıkları

1. Serebral otoregülasyon
2. KPB da serebral otoregülasyon
   - Akım-basınç
   - Sıcaklık
   - Anemi
3. Anemi-transfüzyon eşik değerinin belirlenmesinde rSO2 monitörizasyonun yeri

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PLoS COMPUTATIONAL BIOLOGY

A Nonlinear Dynamic Approach Reveals a Long-Term Stroke Effect on Cerebral Blood Flow Regulation at Multiple Time Scales

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Abstract

Cerebral autoregulation (CA) is an important vascular control mechanism responsible for relatively stable cerebral blood flow despite changes of systemic blood pressure (BP). Impaired CA may leave brain tissue unprotected against potentially harmful effects of BP fluctuations. It is generally accepted that CA is less effective or even inactive at frequencies >~0.1 Hz. Without any physiological foundation, this concept is based on studies that quantified the coupling between BP and cerebral blood flow velocity (BFV) using transfer function analysis. This traditional analysis assumes stationary oscillations with constant amplitude and period, and may be unreliable or even invalid for analysis of nonstationary BP and BFV signals. In this study we propose a novel computational tool for CA assessment that is based on nonlinear dynamic theory without the assumption of stationary signals. Using this method, we studied BP and BFV recordings collected from 39 patients with chronic ischemic infarctions and 40 age-matched non-stroke subjects during baseline resting conditions. The active CA function in non-stroke subjects was associated with an advanced phase in BFV oscillations compared to BP oscillations at frequencies from ~0.02 to 0.38 Hz. The phase shift was reduced in stroke patients even at >=6 months after stroke, and

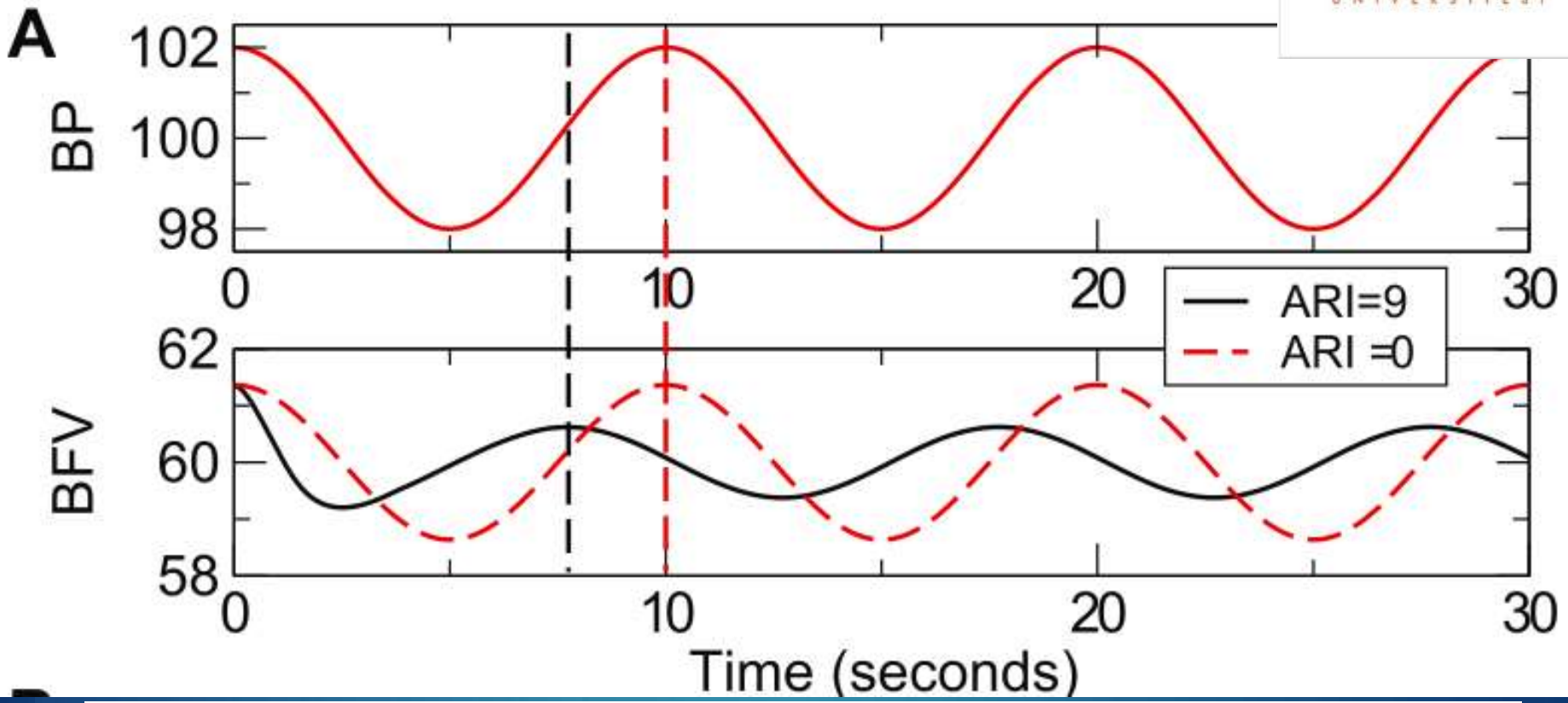
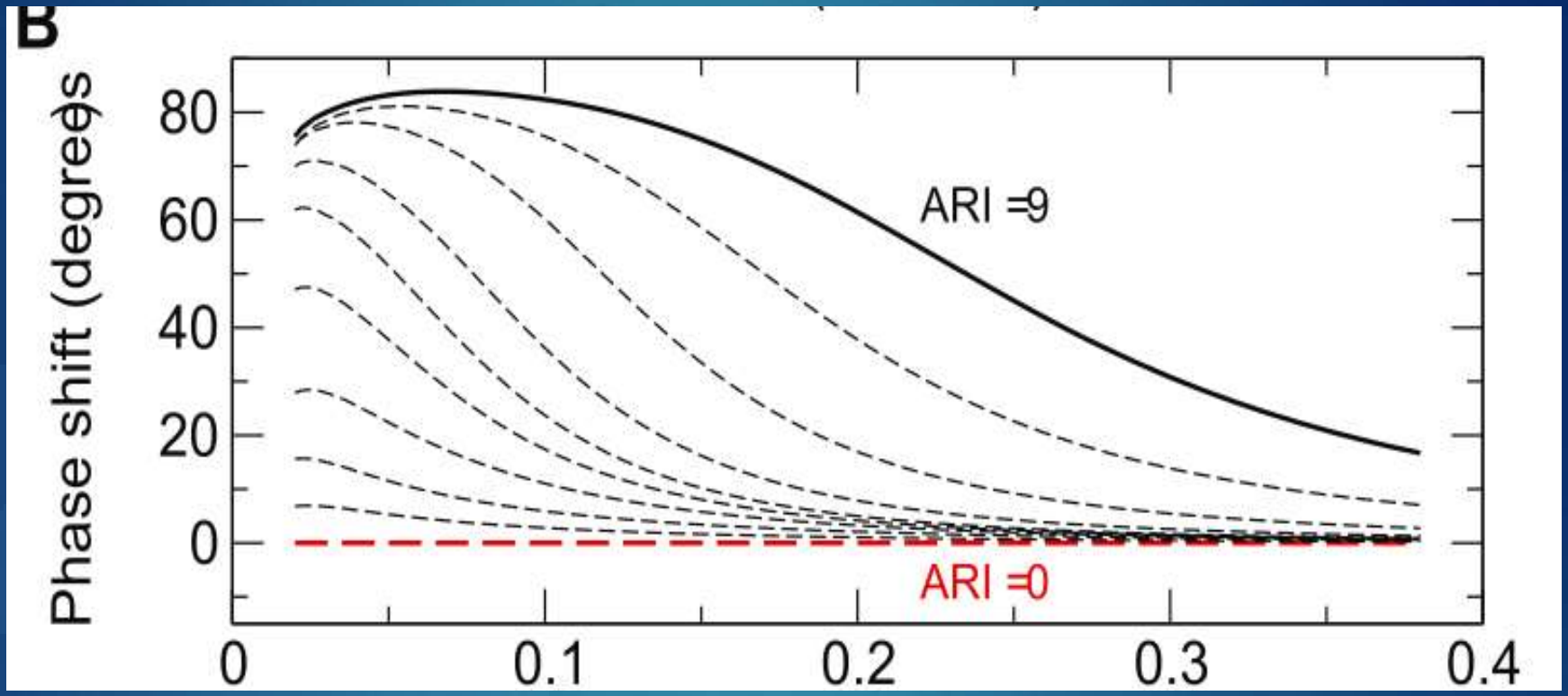
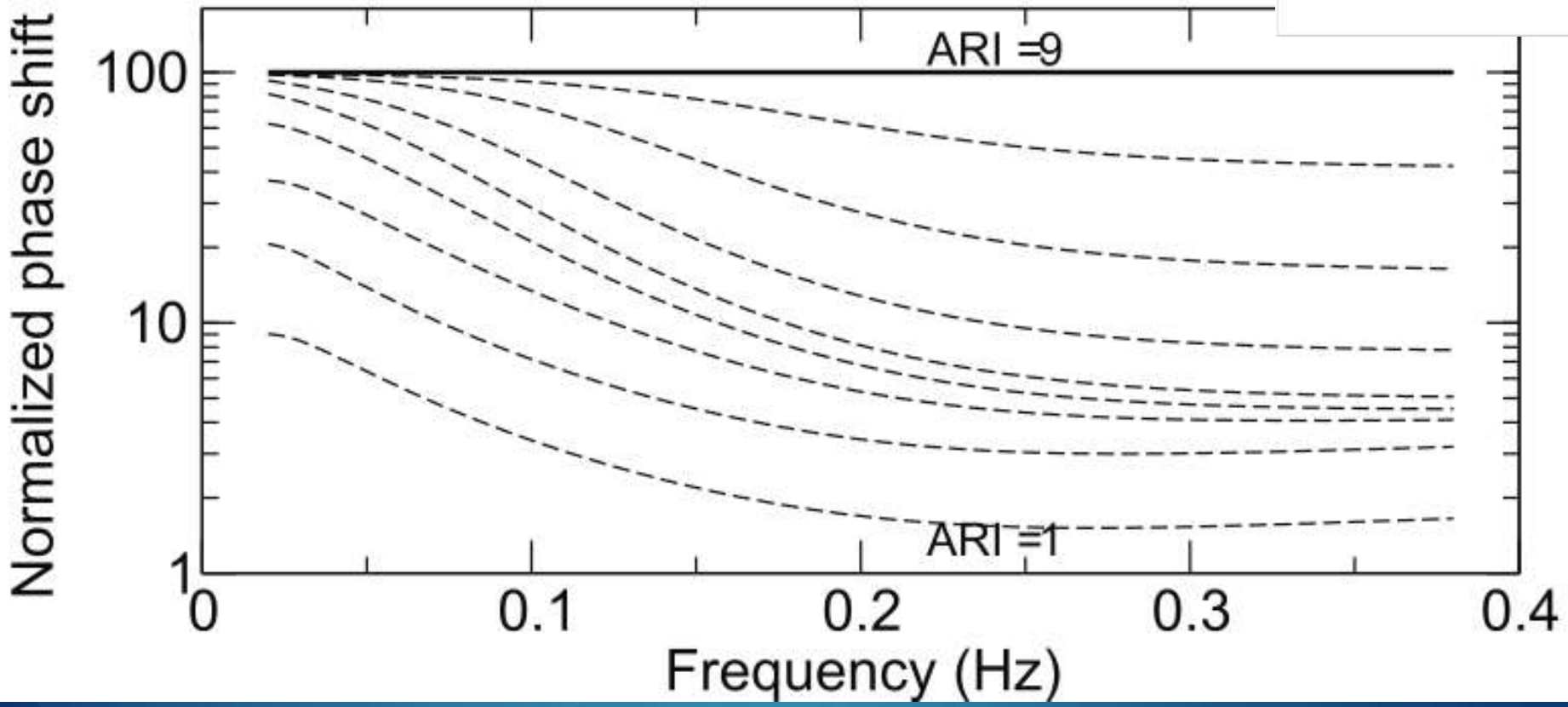


Figure 5. Frequency-dependent phase shift between BP and BFV oscillations in the Aaslid-Tiecks model. (**A**) BP oscillations at certain frequency induced oscillations in BFV at the same frequency. In the Aaslid-Tiecks model [56], cerebral autoregulation is estimated by a dynamic autoregulation index (ARI) that ranges from 0 (absence of cerebral autoregulation) to 9 (best autoregulation). When cerebral autoregulation is absent (ARI = 0), there is no phase shift between BP and BFV oscillations, i.e., the locations of BFV and BP peaks coincide.



(**B**) BFV-BP phase shift at different frequencies for different auto-regulation (ARI = 0 to 9 from bottom to top). (**C**) Normalized BFV-BP



regulation (ARI = 0 to 9 from bottom to top). (**C**) Normalized BFV-BP phase shift as percentages of values of ARI = 9. Curves from bottom to top correspond to ARI = 1 to 9, respectively. Note that y axis was in log scale. Results in B and C showed that BFV-BP phase shift decreased with increasing frequency and that phase shift is larger for larger ARI at all tested frequencies (0.02–0.38 Hz).

SEREBRAL OTOREGÜLASYON ÖLÇÜMLERİ

Pressure Reactivity Index (PRx)

- MAP ve CBV / ICP dalgası ilişkisinin analizi
- -1 ile +1 arasında
- ***Pozitif değer;*** CPP, arteriyal basınçla ilişkili → bozulmuş serebral otoregülasyon
- ***Negatif değer;*** CPP, arteriyal basınçla ilişkisiz → serebral otoregülasyon intakt

SEREBRAL OTOREGÜLASYON ÖLÇÜMLERİ

Tissue Oxygenation Index (Tox)

- NIRS ile ölçülür
- MAP'daki akut değişiklikler ile doku oksijenasyonu ilişkisi

Autoregulatory Index (ARI)

- MAP'daki değişikliğe CVR'daki yanıtın değerlendirilmesi
- Otoregülasyon kapasitesi
- 0; bozulmuş otoregülasyon
- 1; mükemmel korunmuş otoregülasyon

$$ARI = \frac{\%\Delta CVR}{\%\Delta CPP}$$

SEREBRAL OTOREGÜLASYON ÖLÇÜMLERİ

Karbondioksit Reaktivitesi

- Serebral damarların $PaCO_2$'ye duyarlılığı
- Mekanik ventilatöre bağlı hastada hipo/hiperventilasyon ile CBF değişimleri izlenir

$$Cerebrovascular\,CO_2 = \frac{\Delta CBF(\%)}{\Delta PaCO_2(mmHg)}$$

ACIBADEM
ÜNİVERSİTESİ

Real-Time Continuous Monitoring of Cerebral Blood Flow Autoregulation Using Near-Infrared Spectroscopy in Patients Undergoing Cardiopulmonary Bypass

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Background and Purpose—Individualizing mean arterial blood pressure targets to a patient's cerebral blood flow autoregulatory range might prevent brain ischemia for patients undergoing cardiopulmonary bypass (CPB). This study compares the accuracy of real-time cerebral blood flow autoregulation monitoring using near-infrared spectroscopy with that of transcranial Doppler.

Methods—Sixty adult patients undergoing CPB had transcranial Doppler monitoring of middle cerebral artery blood flow velocity and near-infrared spectroscopy monitoring. The mean velocity index (Mx) was calculated as a moving, linear correlation coefficient between slow waves of middle cerebral artery blood flow velocity and mean arterial blood pressure. The cerebral oximetry index was calculated as a similar coefficient between slow waves of cerebral oximetry and mean arterial blood pressure. When cerebral blood flow is autoregulated, Mx and cerebral oximetry index vary around zero. Loss of autoregulation results in progressively more positive Mx and cerebral oximetry index.

Results—Mx and cerebral oximetry index showed significant correlation (r=0.55, P<0.0001) and good agreement (bias, 0.08±0.18, 95% limits of agreement: −0.27 to 0.43) during CPB. Autoregulation was disturbed in this cohort during CPB (average Mx 0.38, 95% CI 0.34 to 0.43). The lower cerebral blood flow autoregulatory threshold (defined as incremental increase in Mx >0.45) during CPB ranged from 45 to 80 mm Hg.

Conclusions—Cerebral blood flow autoregulation can be monitored continuously with near-infrared spectroscopy in adult patients undergoing CPB. Real-time autoregulation monitoring may have a role in preventing injurious hypotension during CPB.

Clinical Trials Registration—at www.clinicaltrials.gov (NCT00769691). **(*Stroke*. 2010;41:1951-1956.)**

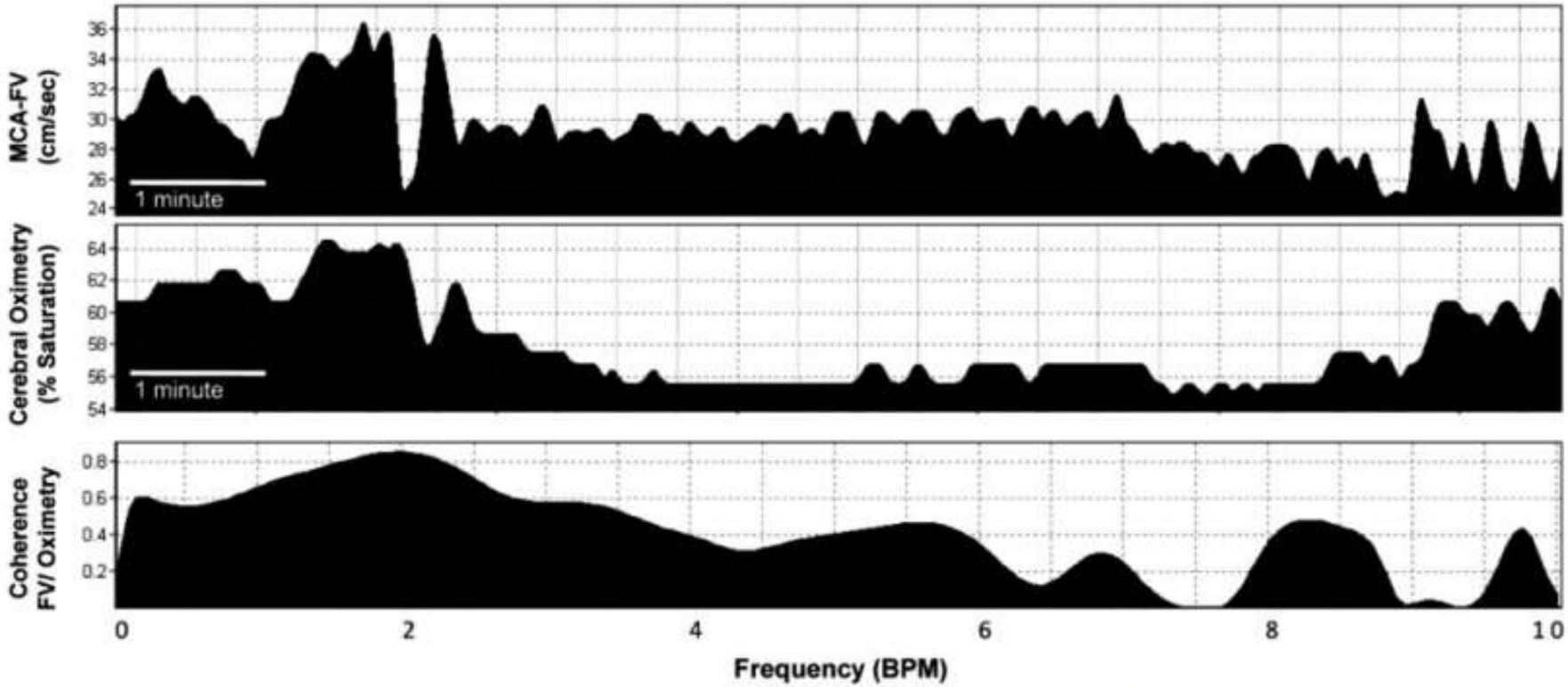

Figure 1. Coherence analysis between middle cerebral artery flow velocity (MCA-FV) and cerebral oximetry. The top panel shows low-pass-filtered MCA-FV across a 12-minute window. The middle panel shows cerebral oximetry across the same time window. The bottom panel shows coherence between MCA-FV and cerebral oximetry as a function of frequency from the 12-minute window shown. The maximum coherence at the frequency of slow waves (0.4 to 4 beats per minute) was averaged across the entire monitoring period to give the results reported.

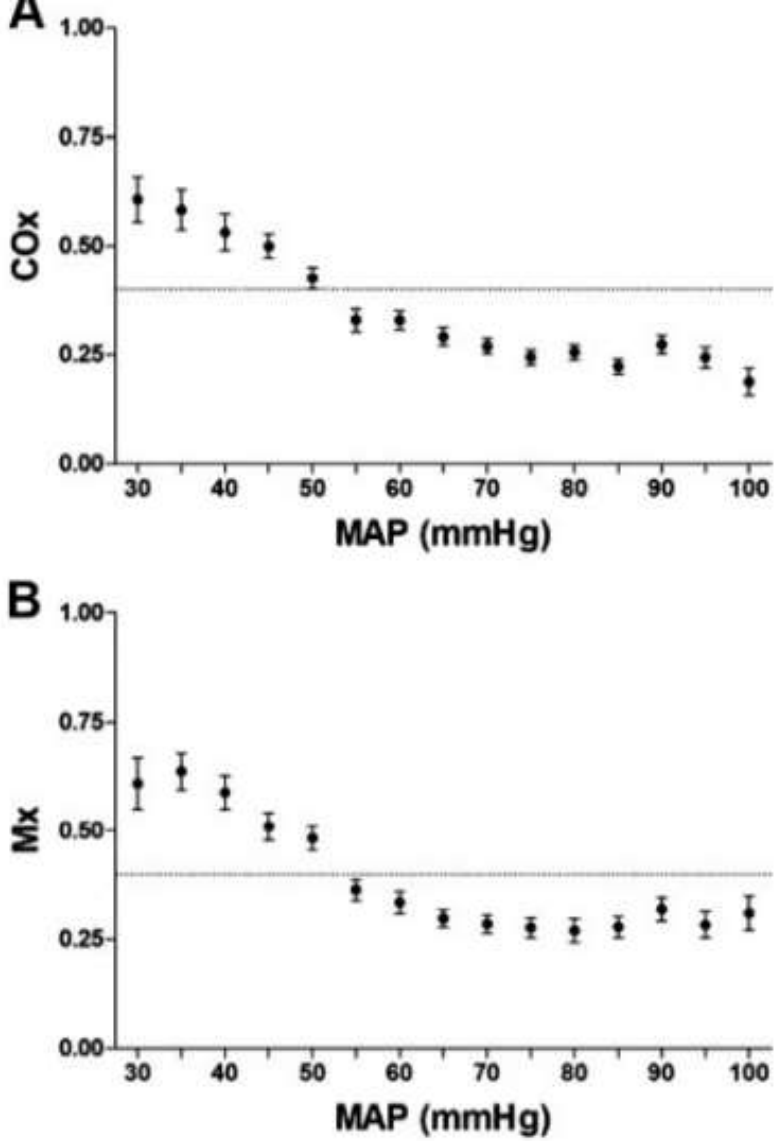

Figure 3. Distribution of COx and Mx over MAP during CPB for the study cohort. A, COx values (mean±SD) are binned to the corresponding MAP at the time of the measurement. B, Simultaneous reading of Mx (mean±SD) is also binned to the corresponding MAP. Note that a wide range of MAP is covered during CPB with a significant increase (impaired autoregulation) in both the COx and Mx at lower MAP.

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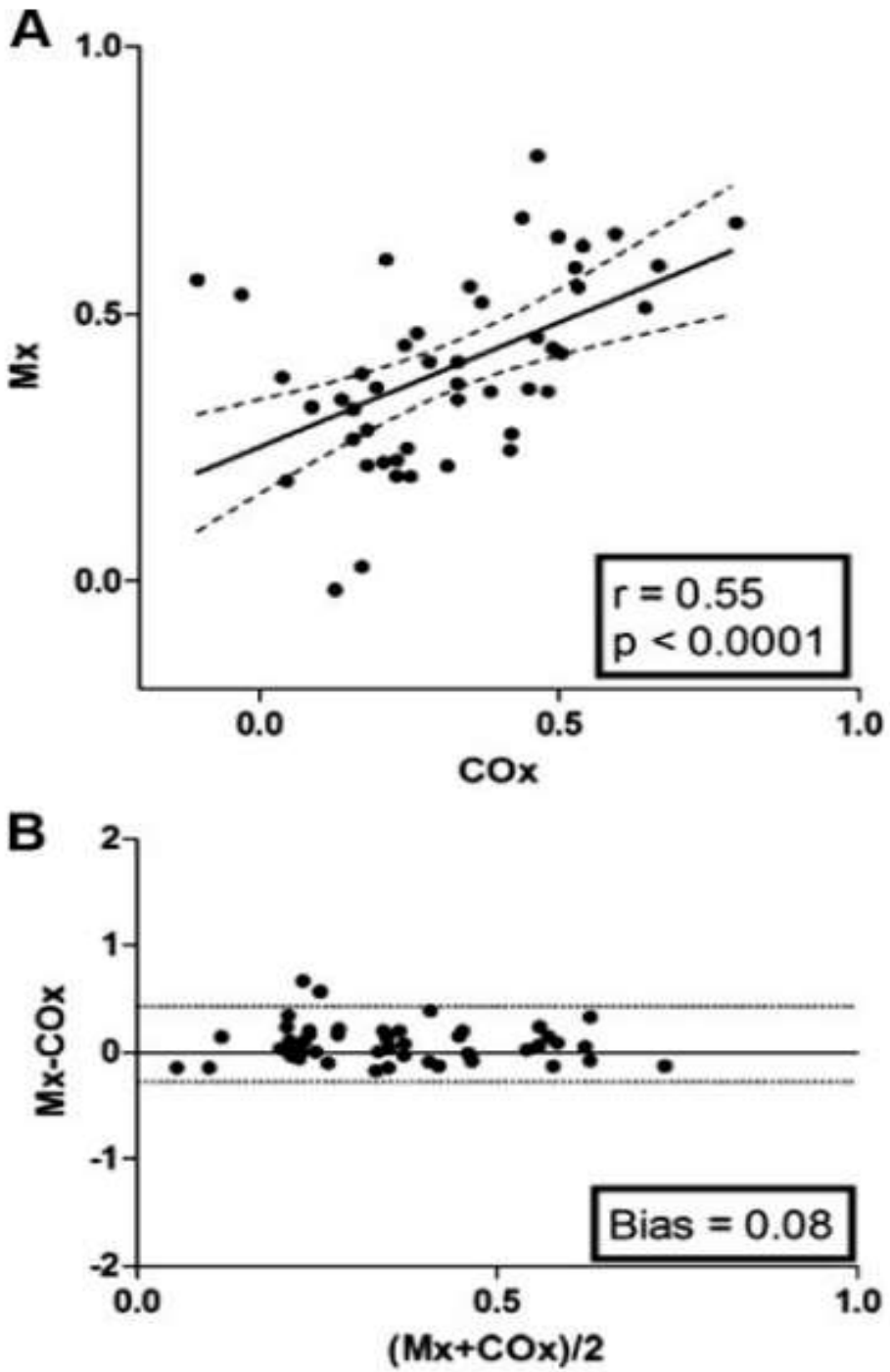
ÜNİVERSİTESİ


A
1.0
0.5
0.0
Mx
r = 0.55
p < 0.0001
0.0
0.5
1.0
COx
B
2
1
0
-1
-2
Mx-COx
Bias = 0.08
0.0
0.5
1.0
(Mx+COx)/2

KPB

1. Akım
2. Basınç
3. Hemodilüsyon; Hct
4. Sıcaklık
5. Nonpulsalite akım

ACIBADEM ÜNİVERSİTESİ

Open Anesthesia

Pressure vs. Flow

Fundamental to CPB is the delivery of oxygen to organs that need it. Because flow is a function of pressure gradient and vascular resistance, from a purely teleological standpoint, it would appear that maximizing blood flow (as opposed to maximizing pressure, which may or may not maximize flow, depending on vascular resistance) would be the most rational approach to CPB management. That said, despite over 50 years of experience and research, **the ideal blood flow and/or perfusion pressure is not known. Nor is it known whether flow or pressure is more important**

There are several problems with maximizing flows. First, **higher flow rates are associated with significant trauma** (to hematologic elements) **and increase the inflammatory response** to CPB. Second, **increased flows carry an increased embolic burden**. Third, **an increase in total flows does not assure increased DO2 to organs of interest**, because the CPB machine cannot alter regional flows. Thus, if CPB flow rates are increased by perfusing relatively unimportant tissue beds, the increase in trauma/inflammation cannot be justified and might be harmful. With regards to the latter, Slater et al studied regional flow rates in pigs on CPB, and found that **regional flows to the brain, kidney, and pancreas all decreased when flows were increased from1.6 to 1.9 L/min/m2** [Slater JM et al. Ann Thorac Surg 72: 542, 2001]. Indeed, at these high levels, brain and kidney flows were at 65% and 55% of pre-CPB flow rates, respectively. This data is similar to Rogers et al.'s human data which showed that **increasing CPB from 1.75 to 2.25 L/min/m2 has no effect on cerebral blood flow or cerebral metabolic rate consumption in humans** [Rogers AT et al. J Thorac Cardiovasc Surg 103: 363, 1992], and consistent with Govier et al.'s data which showed that **changes in flow rates from 1.0 to 2.0 L/min/m2 had no effect on CBF during hypothermic CPB in humans** [Govier AV et al. Ann Thorac Surg 38: 592, 1984]

Interactive CardioVascular and Thoracic Surgery Advance Access published January 12, 2016

Interactive CardioVascular and Thoracic Surgery (2016) 1–7
doi:10.1093/icvts/ivv371

ORIGINAL ARTICLE – ADULT CARDIAC

Cite this article as: Hori D, Hogue C, Adachi H, Max L, Price J, Sciortino C *et al.* Perioperative optimal blood pressure as determined by ultrasound tagged near infrared spectroscopy and its association with postoperative acute kidney injury in cardiac surgery patients. Interact CardioVasc Thorac Surg 2016; doi:10.1093/icvts/ivv371.

Perioperative optimal blood pressure as determined by ultrasound tagged near infrared spectroscopy and its association with postoperative acute kidney injury in cardiac surgery patients

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Received 1 August 2015; received in revised form 4 November 2015; accepted 16 November 2015

Abstract

OBJECTIVES: Perioperative blood pressure management by targeting individualized optimal blood pressure, determined by cerebral blood flow autoregulation monitoring, may ensure sufficient renal perfusion. The purpose of this study was to evaluate changes in the optimal blood pressure for individual patients, determined during cardiopulmonary bypass (CPB) and during early postoperative period in intensive care unit (ICU). A secondary aim was to examine if excursions below optimal blood pressure in the ICU are associated with risk of cardiac surgery-associated acute kidney injury (CSA-AKI).

METHODS: One hundred and ten patients undergoing cardiac surgery had cerebral blood flow monitored with a novel technology using ultrasound tagged near infrared spectroscopy (UT-NIRS) during CPB and in the first 3 h after surgery in the ICU. The correlation flow index (CFx) was calculated as a moving, linear correlation coefficient between cerebral flow index measured using UT-NIRS and mean arterial pressure (MAP). Optimal blood pressure was defined as the MAP with the lowest CFx. Changes in optimal blood pressure in the perioperative period were observed and the association of blood pressure excursions (magnitude and duration) below the optimal blood pressure [area under the curve (AUC) < OptMAP mmHgxh] with incidence of CSA-AKI (defined using Kidney Disease: Improving Global Outcomes criteria) was examined.

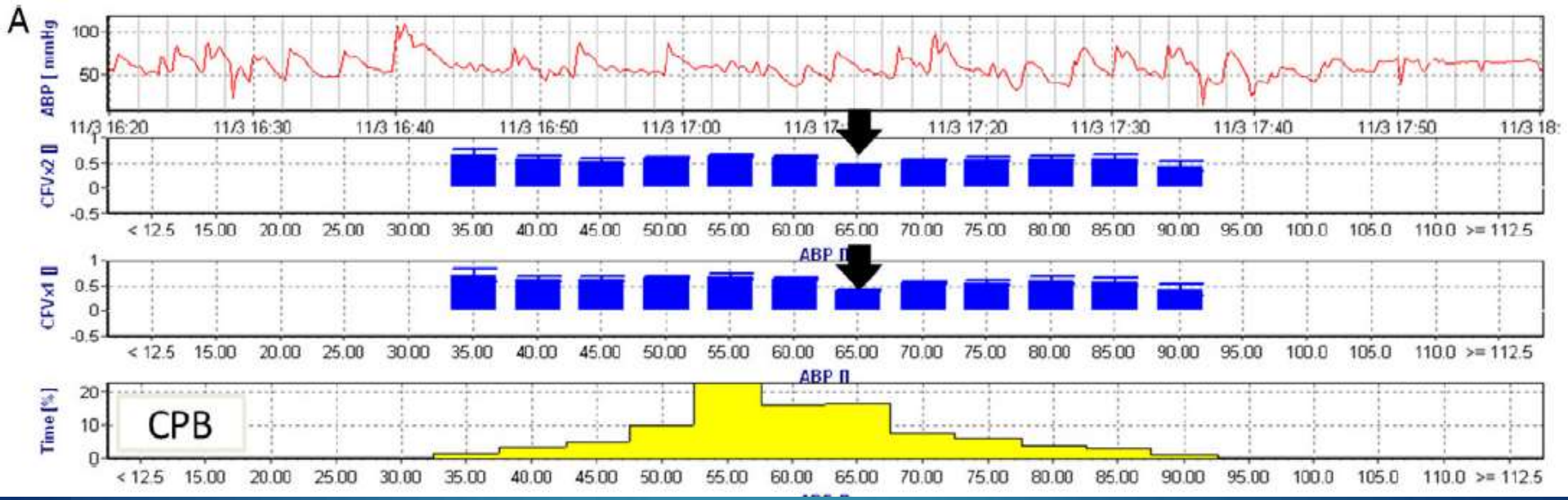

Figure 1: A representative cerebral autoregulation monitoring recording from a single patient obtained during CPB (**A**) and after ICU admission (**B**). The top graph in each recording is the time series of ABP while the next two graphs represent the CFx from the left and right brain hemispheres. The latter represent the average CFx values placed in 5 mmHg blood pressure bins. When cerebral blood flow is in the autoregulated range, CFx is close to zero but when blood pressure is below or above the autoregulation range CFx approaches 1. The bottom graph (**B**) represents the percentage of time during the recording where blood pressure was in each 5

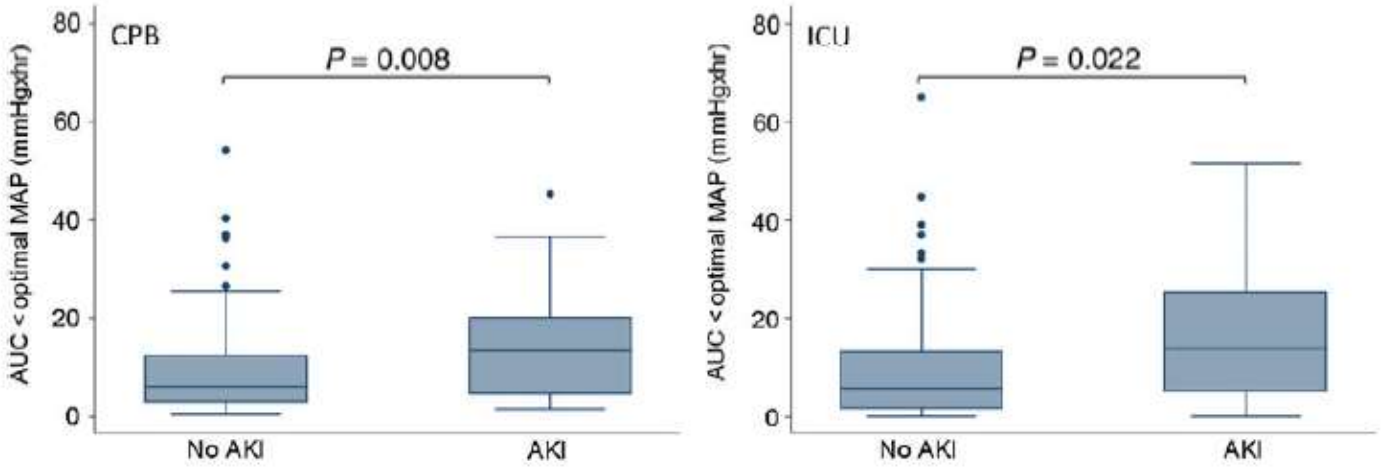

Figure 3: Box and whisker plot showing blood pressure excursion below the optimal blood pressure during CPB and in the ICU for patients with and without CSA-AKI. The horizontal line in the shaded box represents the median value, and the shaded box represents the interquartile range. The error bars below and above the shaded area represents ±1.5 × the interquartile range; points beyond the error bar are outliers. CPB: cardiopulmonary bypass; ICU: intensive care unit; CSA-AKI: cardiac surgery-associated acute kidney injury.

SONUÇ

- Kabul edilebilir sınırlar içindeki POMPA AKIMI ve BASINCI bile;
  - Kişiselleştirilmiş fizyolojik farklılıklar nedeni ile
  - Güvenli olmayabilir.

Impaired Autoregulation of Cerebral Blood Flow During Rewarming from Hypothermic Cardiopulmonary Bypass and Its Potential Association with Stroke

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BACKGROUND: Patient rewarming after hypothermic cardiopulmonary bypass (CPB) has been linked to brain injury after cardiac surgery. In this study, we evaluated whether cooling and then rewarming of body temperature during CPB in adult patients is associated with alterations in cerebral blood flow (CBF)–blood pressure autoregulation.

METHODS: One hundred twenty-seven adult patients undergoing CPB during cardiac surgery had transcranial Doppler monitoring of the right and left middle cerebral artery blood flow velocity. Eleven patients undergoing CPB who had arterial inflow maintained at >35°C served as controls. The mean velocity index (Mx) was calculated as a moving, linear correlation coefficient between slow waves of middle cerebral artery blood flow velocity and mean arterial blood pressure. Intact CBF–blood pressure autoregulation is associated with an Mx that approaches 0. Impaired autoregulation results in an increasing Mx approaching 1.0. Comparisons of time-averaged Mx values were made between the following periods: before CPB (baseline), during the cooling and rewarming phases of CPB, and after CPB. The number of patients in each phase of CPB with an Mx >4.0, indicative of impaired CBF autoregulation, was determined.

RESULTS: During cooling, Mx (left, 0.29 ± 0.18; right, 0.28 ± 0.18 [mean ± SD]) was greater than that at baseline (left, 0.17 ± 0.21; right, 0.17 ± 0.20; $P \leq 0.0001$). Mx increased during the rewarming phase of CPB (left, 0.40 ± 0.19; right, 0.39 ± 0.19) compared with baseline ($P \leq 0.001$) and the cooling phase ($P \leq 0.0001$), indicating impaired CBF autoregulation. After CPB, Mx (left, 0.27 ± 0.20; right, 0.28 ± 0.21) was higher than at baseline (left, $P = 0.0004$; right, $P = 0.0003$), no different than during the cooling phase, but lower than during rewarming (left, $P \leq 0.0001$; right, $P \leq 0.0005$). Forty-three patients (34%) had an Mx ≥0.4 during the cooling phase of CPB and 68 (53%) had an average Mx ≥0.4 during rewarming. Nine of the 11 warm controls had an average Mx ≥0.4 during the entire CPB period. There were 7 strokes and 1 TIA after surgery. All strokes were in patients with Mx ≥ 0.4 during rewarming ($P = 0.015$). The unadjusted odds ratio for any neurologic event (stroke or transient ischemic attack) for patients with Mx ≥ 0.4 during rewarming was 6.57 (95% confidence interval, 0.79 to 55.0, $P < 0.08$).

CONCLUSIONS: Hypothermic CPB is associated with abnormal CBF–blood pressure autoregulation that is worsened with rewarming. We found a high rate of strokes in patients with evidence of impaired CBF autoregulation. Whether a pressure-passive CBF state during rewarming is associated with risk for ischemic brain injury requires further investigation.

(Anesth Analg 2010;110:321–8)

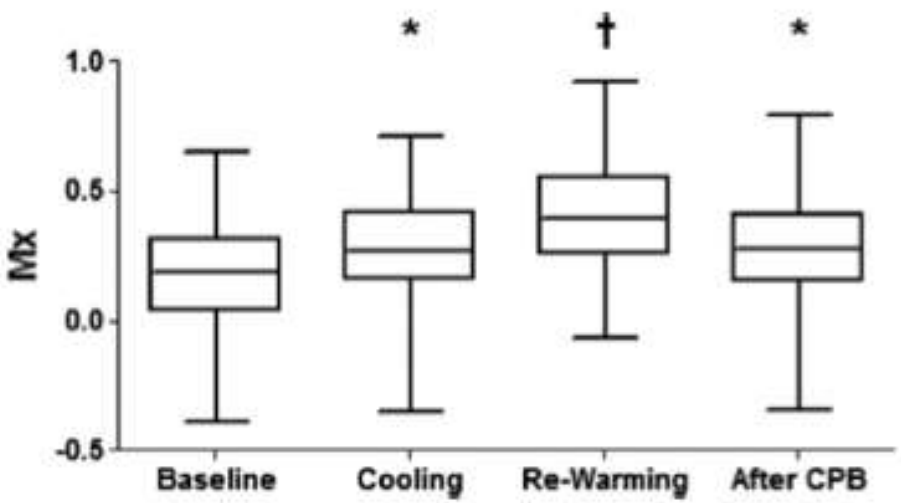

Figure 1. Mean velocity index (Mx) values obtained after anesthesia induction but before cardiopulmonary bypass (CPB) initiation (baseline) and during the cooling and re-warming phases of CPB. Mx is derived as the nonlinear correlation between cerebral blood flow (CBF) velocity of the right and left middle cerebral arteries and mean arterial blood pressure. This unitless measurement is obtained from 300-s windows of data that are updated every 10 s. Functional CBF autoregulation is indicated by values of Mx that approach 0; dysregulation is indicated by Mx values approaching 1.0. An Mx value between 0.3 and 0.5 is likely associated with autoregulation failure.[16–18] *$P \leq 0.001$ versus baseline; †$P \leq 0.0001$ versus cooling phase and baseline.

Table 5. Neurological Outcomes for Patients with and Without Impaired Cerebral Blood Flow Autoregulation During Rewarming on Cardiopulmonary Bypass

Outcome	No impairment ($n = 60$)	Impairment ($n = 67$)	P
Perioperative stroke	0	7 (10.4%)	0.015
Transient ischemic attack	1 (1.7%)	0	0.463

Hemodilution Combined With Hypercapnia Impairs Cerebral Autoregulation During Normothermic Cardiopulmonary Bypass

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Objective: To investigate the influence of hemodilution and arterial pCO_2 on cerebral autoregulation and cerebral vascular CO_2 reactivity.

Design: Prospective interventional study.

Setting: University hospital-based single-center study.

Participants: Forty adult patients undergoing elective cardiac surgery using normothermic cardiopulmonary bypass.

Interventions: Blood pressure variations induced by 6/minute metronome-triggered breathing (baseline) and cyclic 6/min changes of indexed pump flow at 3 levels of arterial pCO_2.

Measurements and Main Results: Based on median hematocrit on bypass, patients were assigned to either a group of a hematocrit $\geq$28% or $<$28%. The autoregulation index was calculated from cerebral blood flow velocity and mean arterial blood pressure using transfer function analysis. Cerebral vascular CO_2 reactivity was calculated using cerebral tissue oximetry data. Cerebral autoregulation as reflected by autoregulation index (baseline 7.5) was significantly affected by arterial pCO_2 (median autoregulation index amounted to 5.7, 4.8, and 2.8 for arterial pCO_2 of 4.0, 5.3, and 6.6 kPa, $p \leq 0.002$) respectively. Hemodilution resulted in a decreased autoregulation index; however, during hypocapnia and normocapnia, there were no significant differences between the two hematocrit groups. Moreover, the autoregulation index was lowest during hypercapnia when hematocrit was $<$28% (autoregulation index 3.3 versus 2.6 for hematocrit $\geq$28% and $<$28%, respectively, $p = 0.014$). Cerebral vascular CO_2 reactivity during hypocapnia was significantly lower when perioperative hematocrit was $<$28% ($p = 0.018$).

Conclusions: Hemodilution down to a hematocrit of $<$28% combined with hypercapnia negatively affects dynamic cerebral autoregulation, which underlines the importance of tight control of both hematocrit and p_aCO_2 during CPB.

KEY WORDS: *cardiopulmonary bypass, cerebral autoregulation, cerebral carbon dioxide reactivity, hemodilution*

Table 1. Patient Demographics and Preoperative Data, Specified for All (n = 40) and Per Perioperative Hematocrit Group

	(n = 40)	≥28%, (n = 21)	<28%, (n = 19)	p Value ≥28% vs <28%
Age (years)	60.1 [55.8-68.6]	58.9 [55.4-68.6]	61.2 [56.4-68.7]	0.566
BSA (m^2)	2.1 [1.9-2.2]	2.1 [1.9-2.2]	2.0 [1.8-2.1]	0.624
Preoperative hematocrit (%)	44.0 [42.3-46.0]	46.0 [43.0-47.0]	43.0 [40.8-44.3]	0.002
ABP (mmHg)	86.0 [78.9-97.0]	86.0 [79.3-98.7]	85.7 [78.1-95.7]	0.578
$S_{ct}O_2$ (%)	71.9 [70.0-73.9]	72.0 [70.4-74.7]	71.0 [68.8-72.3]	0.098
CBFV cm/s	40.3 [34.5-47.6]	39.3 [34.4-47.7]	41.8 [36.5-49.7]	0.561
ARI	7.5 [7.0-8.0]	7.4 [6.5-8.0]	7.5 [7.1-8.0]	0.671

NOTE. Data presented as median [interquartile range].

Abbreviations: BSA, body surface area; ABP, arterial blood pressure; $S_{ct}O_2$, cerebral tissue oxygen saturation; CBFV, cerebral blood flow velocity; ARI, autoregulation index.

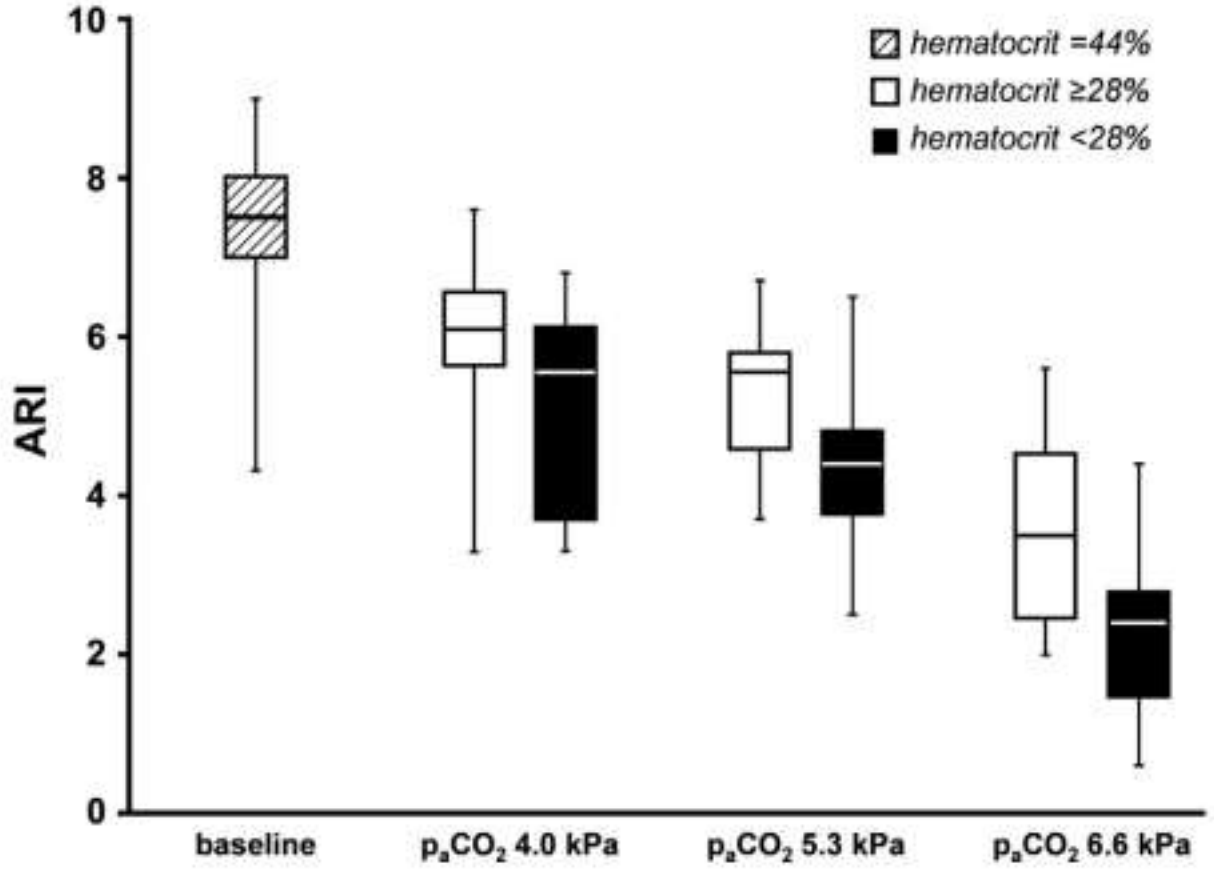

Fig 1. Cerebral autoregulation as indicated by the autoregulation index (ARI) at baseline, at 3 levels of p_aCO_2, and at 2 levels of hematocrit during cardiopulmonary bypass.

Journal of Neurosurgical Anesthesiology
Vol. 13, No. 3, pp. 233–236

ACIBADEM ÜNİVERSİTESİ

Cerebral Autoregulation Before and After Blood Transfusion in a Child

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Summary: The authors present the case of an anemic 22-month-old child undergoing lower extremity surgery in whom the lower limit of cerebral autoregulation was shifted to the right. **Key Words:** Children—Autoregulation—Anemia

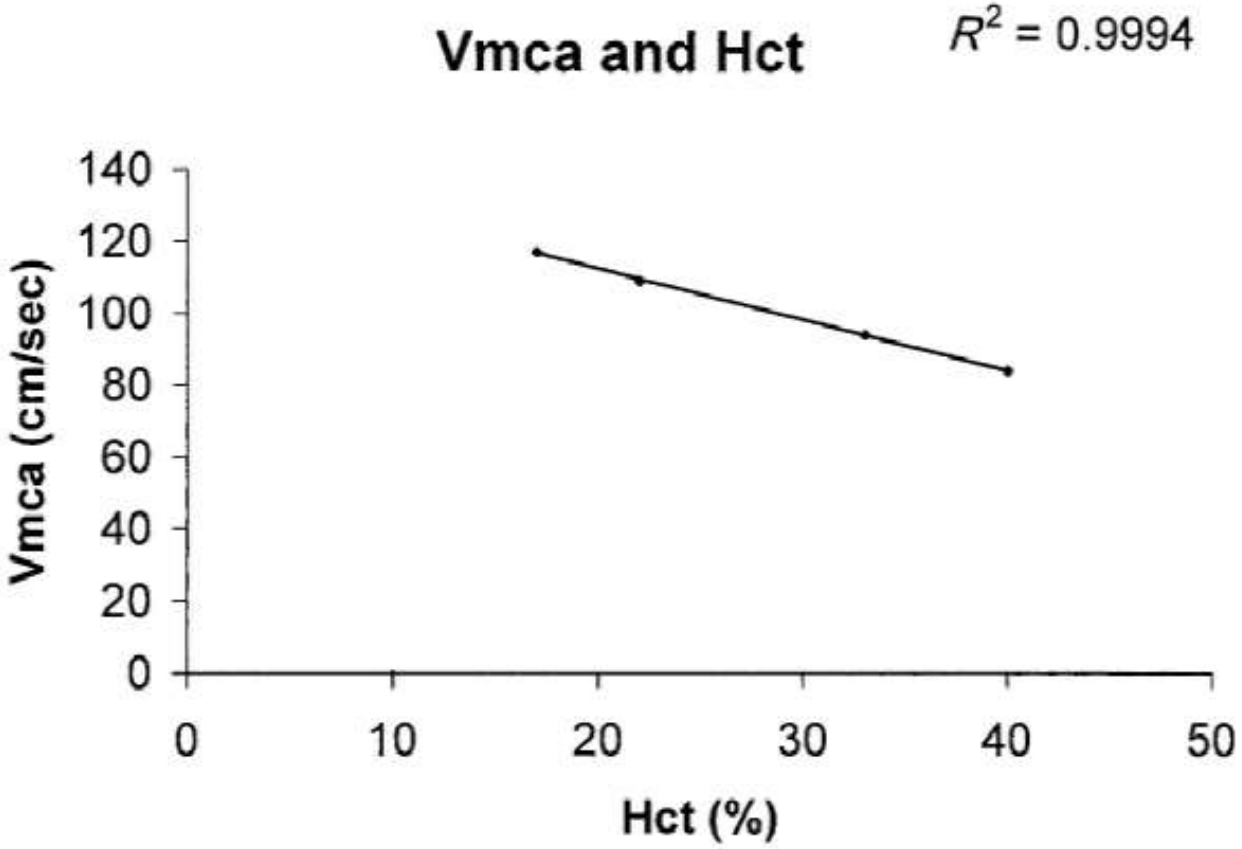

FIG. 1. Left middle cerebral artery blood flow velocity (Vmca) and hematocrit: There is an inverse relationship between hematocrit and Vmca.

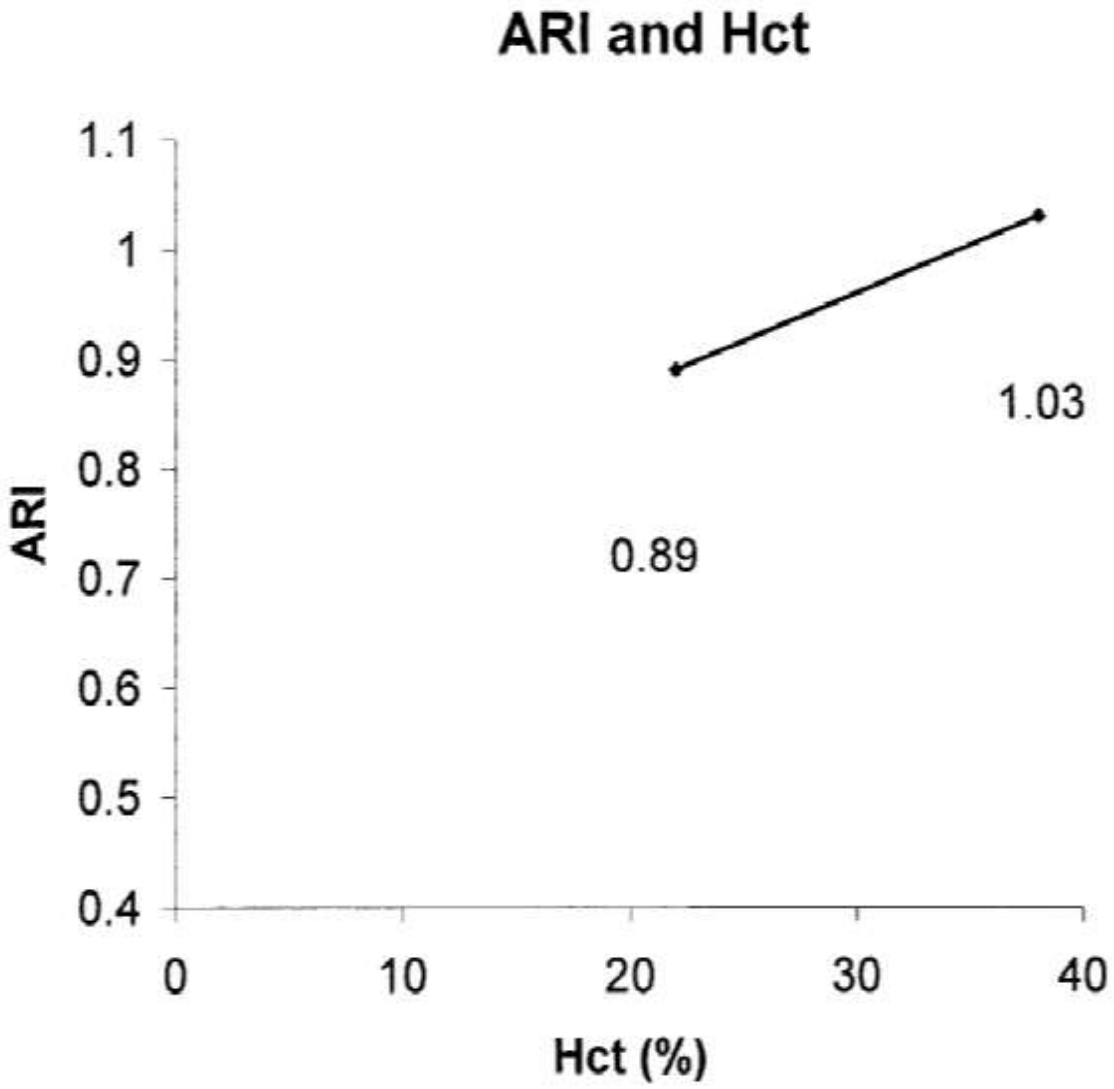

FIG. 2. Autoregulatory index (ARI) and hematocrit: ARI is normal at hematocrit of 22% and 38%. ARI improves with blood transfusion.

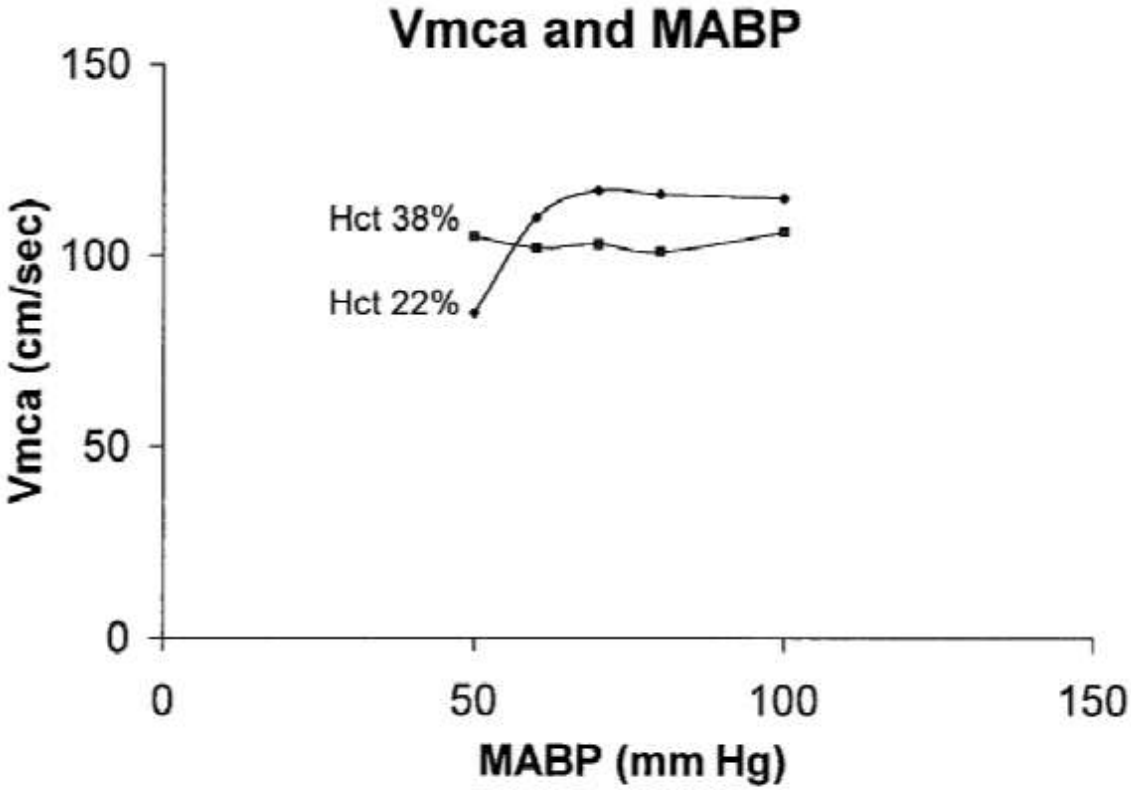

FIG. 3. Left middle cerebral artery blood flow velocity (Vmca) and mean arterial blood pressure (MABP): The lower limit of MABP and Vmca is shifted to the right during anemia. Series 1, hematocrit 22%; Series 2, hematocrit 38%.

The Heart Surgery Forum #2013-293
17 (3), 2014
doi: 10.1532/HSF98.2013293

Online address: http://cardenjennings.metapress.com

Efficacy of Near-Infrared Spectrometry for Monitoring the Cerebral Effects of Severe Dilutional Anemia

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Methods: The prospective observational study involved patients who underwent cerebral rSO_2 monitoring by NIRS during elective isolated first-time CABG: an anemic group (*N*=15) (minimum Hemoglobin (Hb) <7 g/dL at any period during cardiopulmonary bypass (CPB) and a control group (*N*=15) (Hb >8 g/dL during CPB). Mean arterial pressure (MAP), pump blood flow, blood lactate level, pCO_2, pO_2 at five time points and cross-clamp time, extracorporeal circulation time were recorded for each patient. Group results statistically were compared.

During the operation, the following stepwise interventions were carried out when there was >10% decrease in cerebral rSO_2:

1. For patients with Hb ≤5 g/dL during hypothermia and/or Hb ≤6 g/dL during rewarming, at least one red blood cell transfusion was administered.
2. For patients with Hb higher than the above limits:
   a. If partial oxygen pressure (pO_2) was <100 mmHg, the inspiratory oxygen fraction (FiO_2) was increased.
   b. If the reservoir level was adequate, pump blood flow was increased from 2.0-2.5 L/m^2/min to 2.5-3.0 L/m^2/min.
   c. If the reservoir level was low, venous return was increased by one or more of the following: Placing the patient in Trendelenburg position, applying vacuum-assisted venous suction, repositioning the venous cannula, or adding crystalloid.
   d. If MAP was ≤60 mmHg, repeated intravenous boluses of 25 µg Noradrenaline were administered to achieve MAP >60 mmHg.
   e. Transfusions of erythrocyte suspension were administered to achieve Hb >7 g/dL.

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Table 1. Demographic characteristics and operative details for the two study groups

	Anemic group (*N*=15)	Control group (*N*=15)	*P Value*
Age (years)	64.2 ± 7.7	56.8 ± 9.3	.02
Females/Males (%)	80/20	20/80	.03
Preop Hemoglobin (g/dL)	10.3 ± 0.9	14.2 ± 1.3	.001
Extracorporeal circulation time (min)	65 ± 23	53 ± 19	NS
Cross-clamp time (min)	40 ± 21	35 ± 17	NS
Postoperative volume balance (mL)	1226 ± 524	947 ± 584	NS

Table 2. Group results for hemoglobin level prior to anesthetic induction, minimum hemoglobin during extracorporeal circulation, and hemodynamic and arterial blood gas values at time of minimum Hb during extracorporeal circulation.

	Anemic group (*N*=15)	Control group (*N*=15)	*P Value*
Hemoglobin (g/dL) at T1	10.3 ± 0.9	14.2 ± 1.3	.001
Min. Hemoglobin during extracorporeal circulation (g/dL)	6.2 ± 0.4	10.3 ± 1.3	.001
Mean arterial pressure (mmHg)	65 ± 5	56 ± 7	.001
Lactate level (mmol/dL)	1.1 ± 0.3	1.1 ± 0.5	NS
Pump blood flow (L/min/m^2)	2.5 ± 0.2	2.2 ± 0.2	.001
pO_2 (mmHg)	202 ± 43	145 ± 42	.001
pCO_2 (mmHg)	33 ± 3	39 ± 2	.001

pO_2: partial oxygen pressure; pCO_2: partial carbon dioxide pressure; T1: prior to anesthetic induction; NS: Non-sufficient.

Table 3. Oxygen saturation findings and their change in time for the right and left cerebral hemispheres, respectively, in the two study groups.

	Anemic group (N=15)	Control group (N=15)
Right hemisphere:		
rSO_2 (%) at T1	52 ± 9	66 ± 6
rSO_2 (%) at time of lowest Hemoglobin during ECC	49 ± 7	58 ± 6
Change in rSO_2 from T1 to lowest Hemoglobin during ECC (%)	5.7	12
Left hemisphere:		
rSO_2 (%) at T1	54 ± 6	69 ± 7
rSO_2 (%) at time of lowest Hemoglobin during ECC	50 ± 7	58 ± 6
Change in rSO_2 from T1 to lowest Hemoglobin during ECC (%)	7.4	11.5

ECC: extracorporeal circulation; rSO_2: regional oxygen saturation; T1: prior to anesthetic induction.

As a conclusion, our findings suggest that NIRS monitoring of cerebral rSO_2 is an effective method that can assist in decision-making related to blood transfusions aimed at addressing dilutional anemia during CPB.

Vretzakis *et al. Journal of Cardiothoracic Surgery* 2013, **8**:145
http://www.cardiothoracicsurgery.org/content/8/1/145

JOURNAL OF CARDIOTHORACIC SURGERY

RESEARCH ARTICLE Open Access

Monitoring of brain oxygen saturation (INVOS) in a protocol to direct blood transfusions during cardiac surgery: a prospective randomized clinical trial

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Table 3 Hematocrit values, intravenous fluids and fluid balance by group

Hematocrit values (%)	Group A (INVOS, n = 75)	Group B (Control, n = 75)	P
Preoperative	39.54 ± 3.90	40.38 ± 4.53	*0.246*
After arterial line placement	38.45 ± 4.32	38.68 ± 4.40	*0.765*
After anesthesia induction	38.19 ± 4.61	37.84 ± 4.53	*0.655*
After first cardioplegia	20.20 ± 3.60	20.16 ± 3.83	*0.947*
End of CPB	23.07 ± 3.45	23.26 ± 3.03	*0.721*
End of operation	27.55 ± 4.18	27.50 ± 4.15	*0.943*
6 hours in the ICU	28.15 ± 3.38	28.79 ± 3.32	*0.263*
12 hours in the ICU	28.61 ± 3.77	29.29 ± 3.58	*0.254*
Day of discharge	30.67 ± 3.07	31.28 ± 2.58	*0.193*
Fluid balance (ml)			
IV fluids to initiation of CPB	368.5 ± 177.0	416.4 ± 184.6	0.101
Urine to initiation of CPB	110.8 ± 95.9	135.7 ± 127.6	0.164
Fluid balance			
After 1st cardioplegia	2240.2 ± 238.8	2326.0 ± 306.4	0.055
Urine output during CPB	666.2 ± 594.0	694.0 ± 423.0	0.743
Total urine output	1326.2 ± 842.2	1419.3 ± 690.7	0.452
Use of filter, n (%)	8 (10.6%)	9 (12.0%)	0.796
Overall fluid balance	685.4 ± 784.1	809.9 ± 651.1	0.290

Table 4 Transfusion data by group (analysis based on "intention to treat")

	Group A (n = 75)	Group B (n = 75)	P
In OR			
RBC units transfused	18	40	
Patients transfused	14 (18.6%)	25 (33.3%)	*0.040*
RBC per transfused pt	1.29 ± 0.47	1.60 ± 0.58	*0.090*
RBC/pt overall	0.24 ± 0.54	0.53 ± 0.84	*0.011*

SONUÇ

- KPB sırasında;
  - Basınç-akım
  - Sıcaklık-Pco2 değişikliklerine bağlı non fizyolojik bir durum oluşmakta
- Serebral otoregülasyonun bozulma olasılığını ↑
- DM ve HT gibi eşlik eden risk faktörleri, bu olasılık ↑
- Bu şartlar altında ANEMİNİN kompansasyonu ancak NIRS monitorizasyonu ile mümkün olabilir