Closed-loop Control of Perioperative Hypotension

Hôpital Erasme

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ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Conflicts of Interest

Consultant for:

- Edwards Lifesciences
- Aguettant
- Fresenius Kabi
- Baxter
- Getinge

Research Fundings:

- Fresenius Kabi
- Edwards Lifesciences
- European Society of Intensive Care Medicine
- Belgium Society of Anesthesiology
- Biospectal

Paul Brousse

- 5 Operating rooms
- 240 liver resection per year
- 60 Pancreatic surgery per year
- **175 Liver Transplant per year** → 3rd largest in Europe

Henri Bismuth

Chairman:
Rene Adam

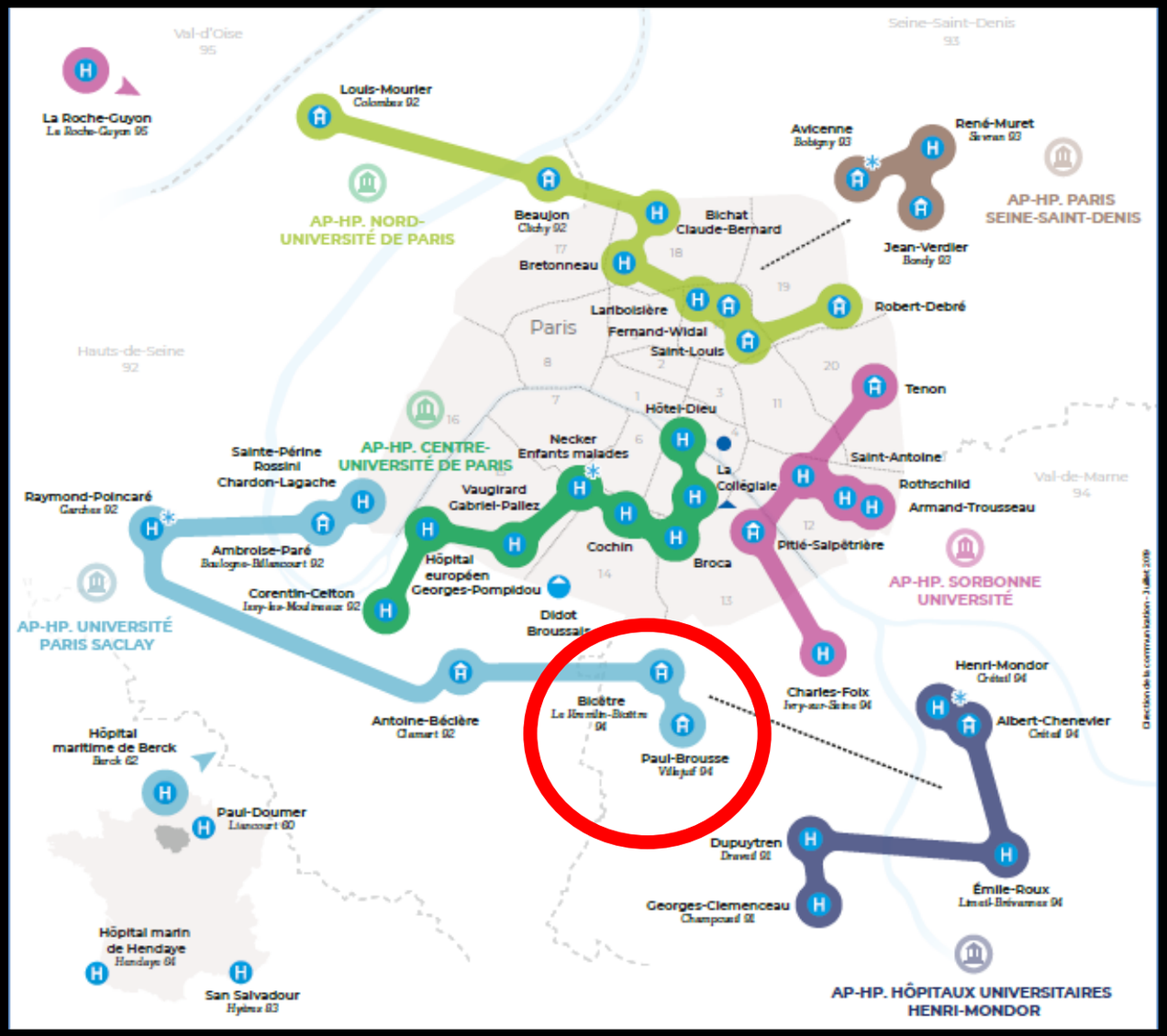
1974: First liver transplant in FRANCE
1982: First description of a « split »

APHP: The greatest university hospital in Europe

- 39 hospitals
- 100,000 professionals
- Connected to 5 medical universities and 17 nursing schools
- 1st biomedical research center in Europe
- 69 rare disease reference centers
- An operating budget of 7.5 billion euros

AP-HP:

- 10 millions of patients
- 200 000 surgeries/ year
- 1250 transplants / year



« We must delve into the roots of the past to discern the bearing branches of our future »

Jules Verne
1828 - 1905

1935

2015

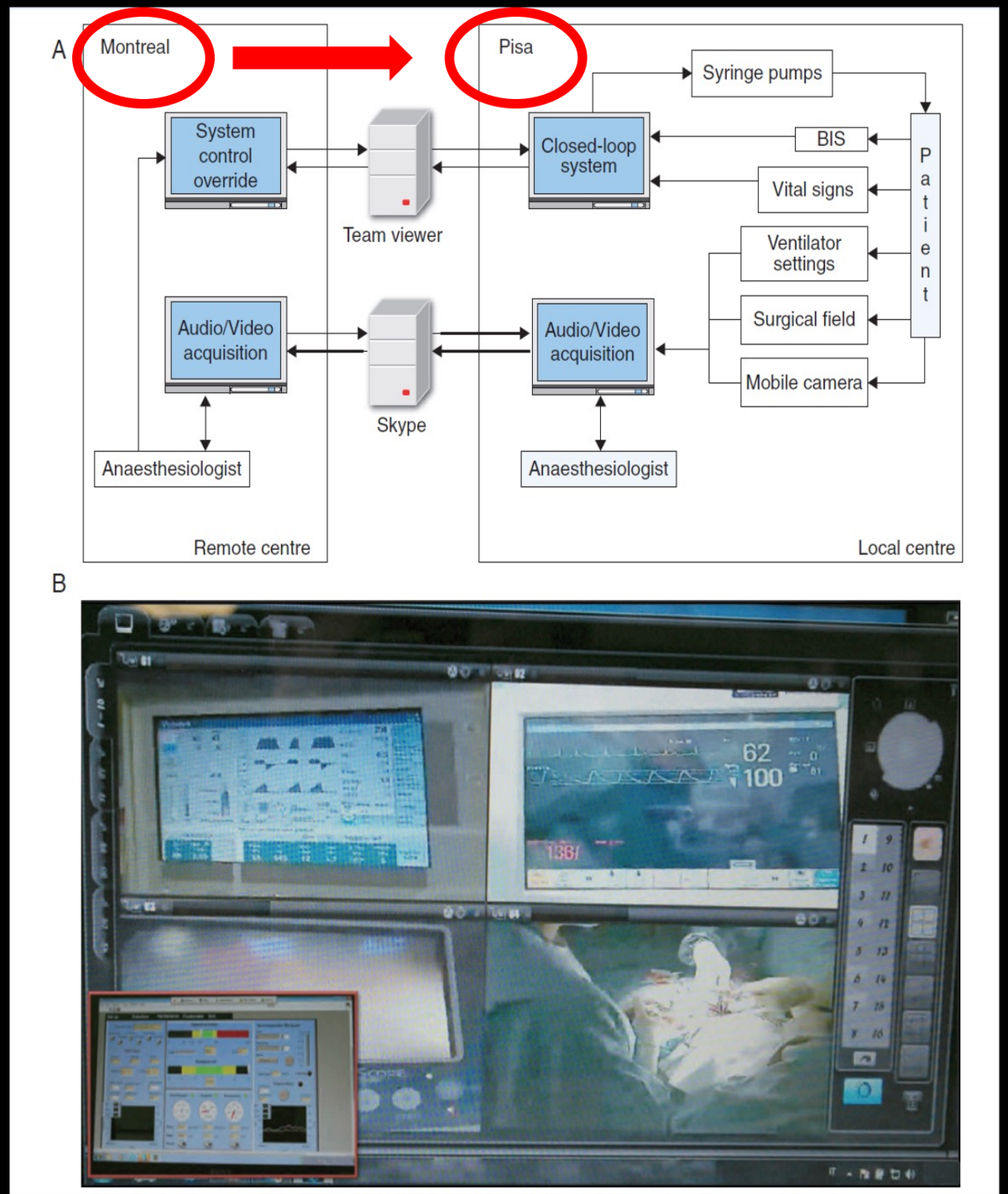
British Journal of Anaesthesia **110** (5): 758–63 (2013)
Advance Access publication 10 March 2013 · doi:10.1093/bja/aes498

BJA

Transcontinental anaesthesia: a pilot study

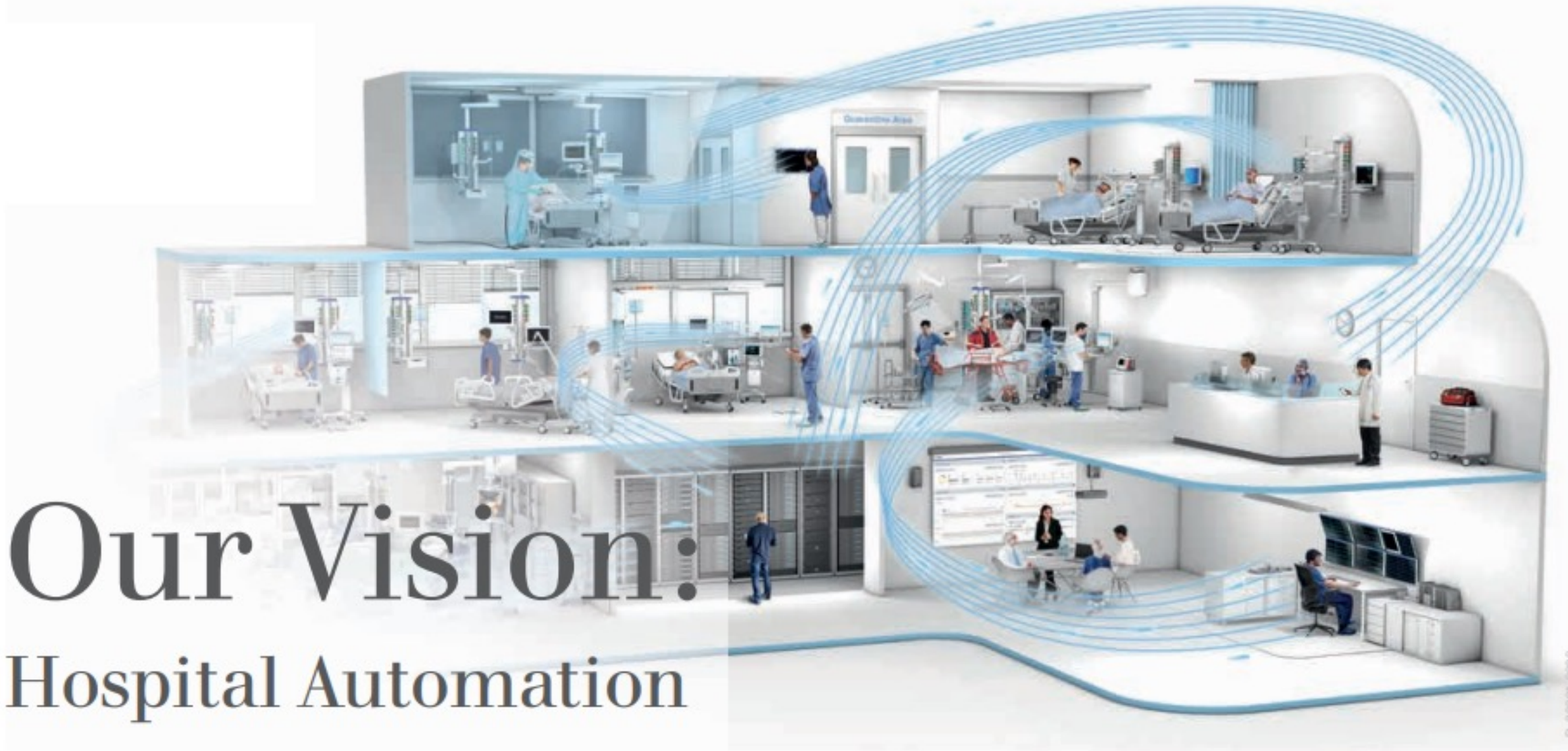
2013

T. M. Hemmerling[1*], E. Arbeid[1], M. Wehbe[1], S. Cyr[1], F. Giunta[2] and C. Zaouter[2]



The transcontinental approach was performed in order to deliver a proof of concept in a setting without specific Internet set-up other than standard Internet communication. Globally, there is a severe lack of specialists and specialist treatment in medicine, especially in anaesthesia, for example, only nine anaesthesiologists are available in Rwanda for a population of more than 10 million.[19] But even in highly industrialized countries such as Canada, a significant population lives in remote regions away from tertiary healthcare centres. Teleanaesthesia could help to overcome the shortage of specialists in remote areas, and it can potentially reduce travel costs and improve patients' accessibility to professional consultations and treatments.

In conclusion, distant preoperative assessment and distant control of anaesthesia are feasible via standard means of Internet communication.



Our Vision:

Hospital Automation

"Helping to reduce the number of preventable deaths in hospitals is a pledge that I made. My personal goal goes beyond: Improving Acute Care with technologies and services that lead to therapy assistance and ultimately to hospital automation."
Stefan Dräger, Chairman and CEO (2018)

We envision a future where human capabilities to deliver patient care in high acuity environments are enhanced by interoperability. Medical devices will be connected as systems and interact with one another, enabling new clinical applications in a safe and secure network. These new clinical applications include decision-supporting technologies, remote control capabilities or automated processes.

Volume 83 | Number 7 | July 2019

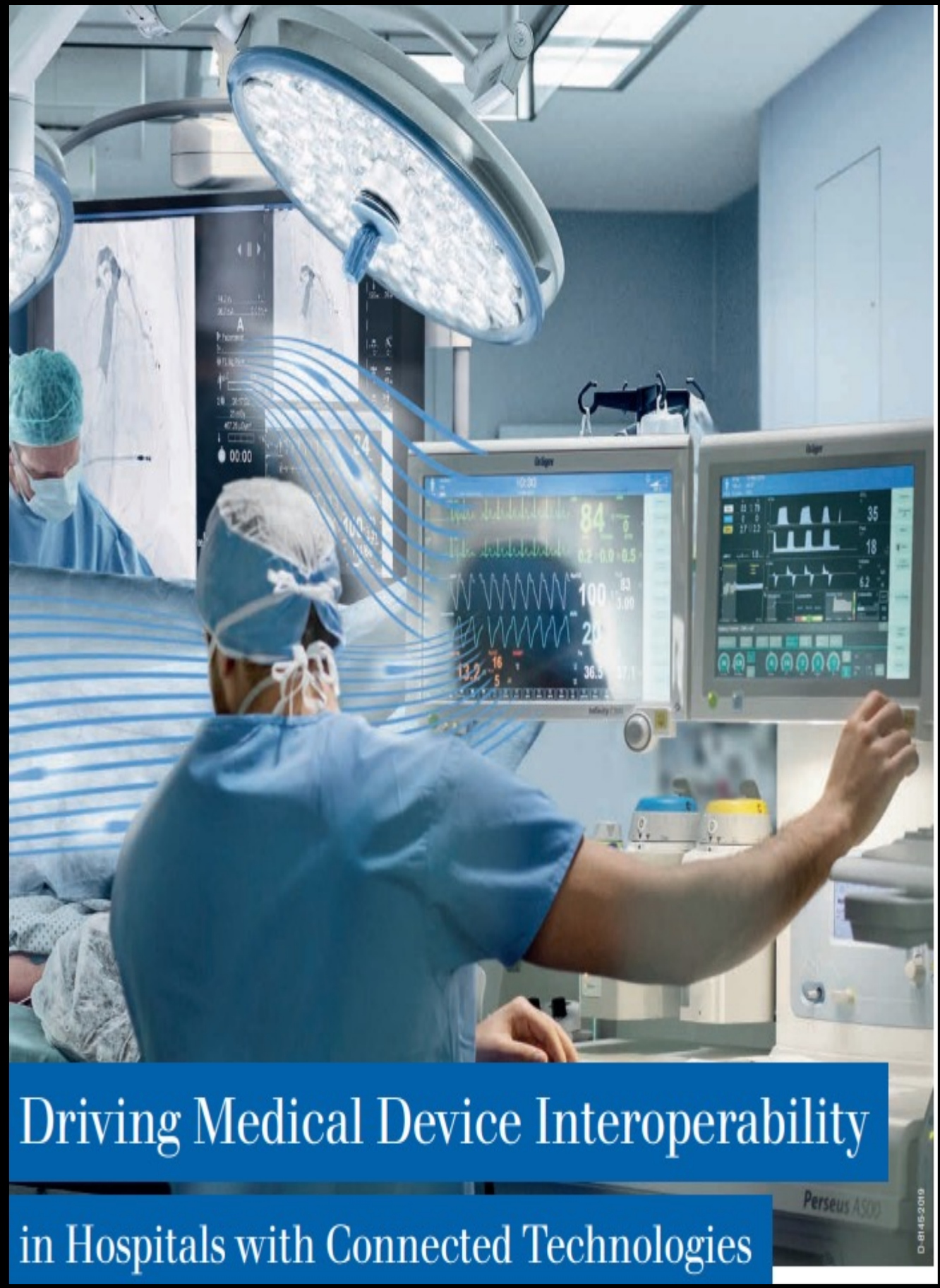
ASA Monitor®

The Newsletter of the American Society of Anesthesiologists

Well-Equipped

On the Cutting Edge of

O.R. Safety and Design



Driving Medical Device Interoperability

in Hospitals with Connected Technologies

From Heroism to Safe Design

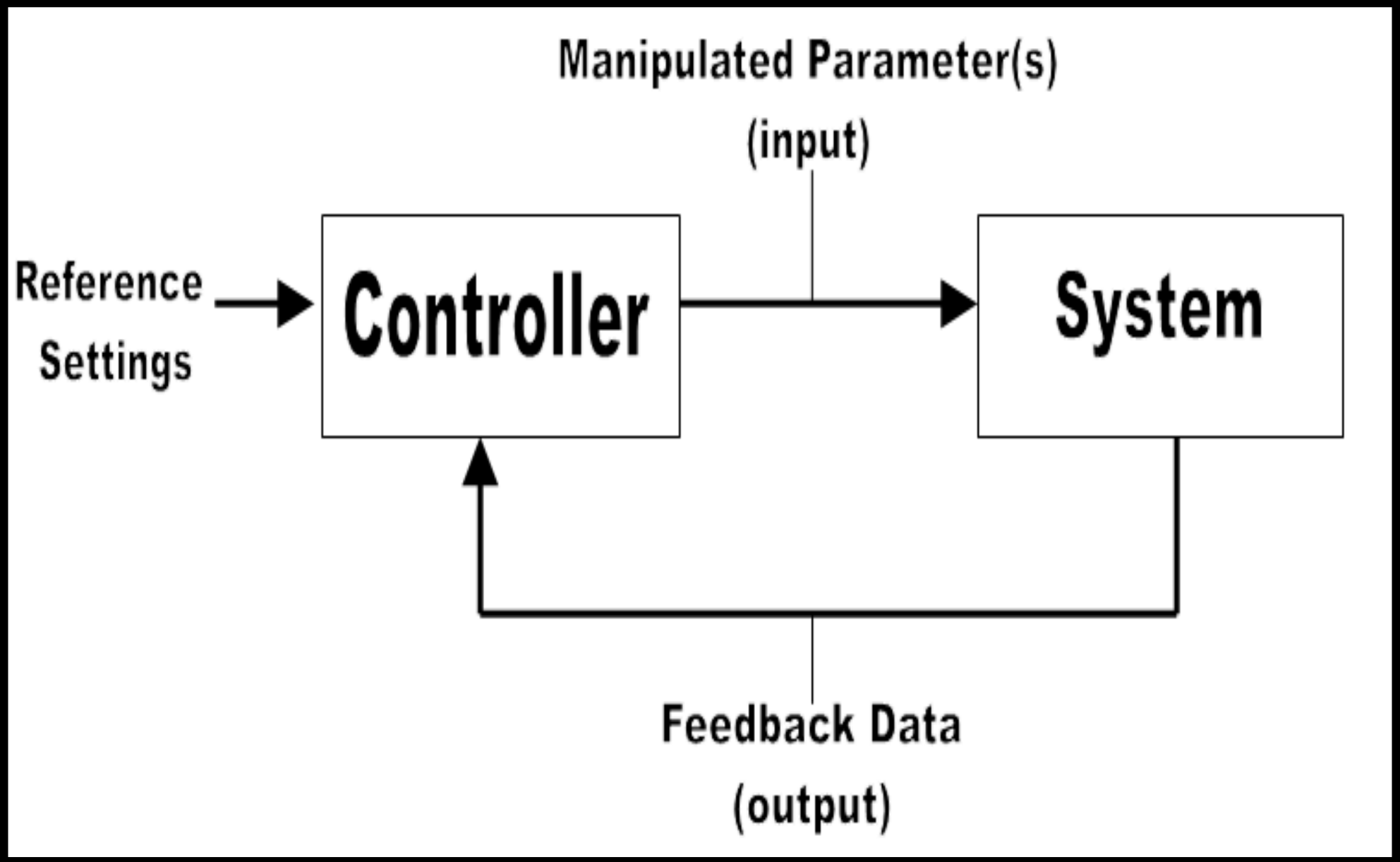
Leveraging Technology

Anesthesiology 2014

Peter J. Pronovost, M.D., Ph.D., George W. Bo-Linn, M.D., M.H.A., Adam Sapirstein, M.D.

"To improve patient safety and productivity, patients and clinicians need a health-care information ecosystem with integrated technologies that support the clinician's work, provide safety nets, and improve productivity."

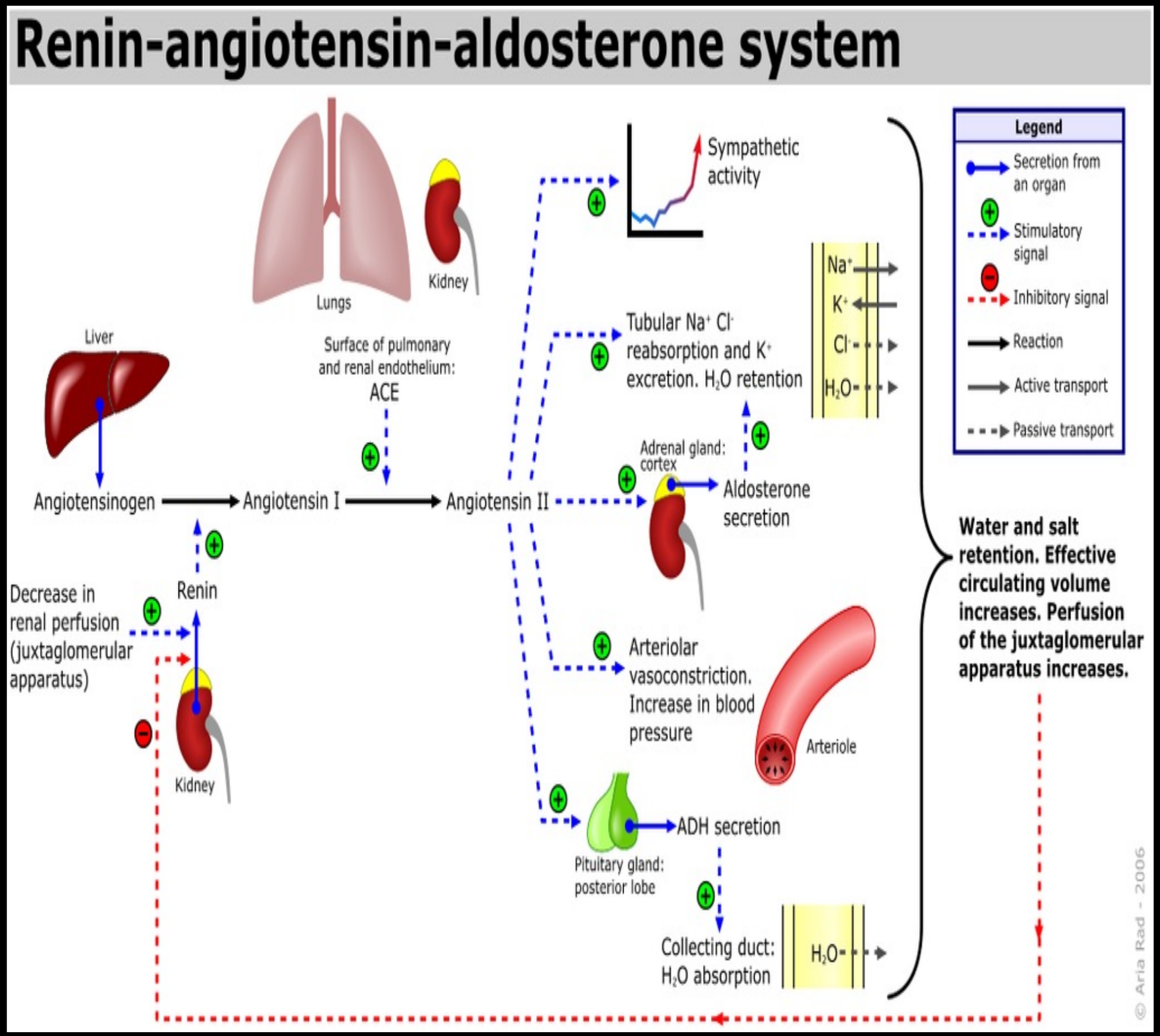
Closed Loop System

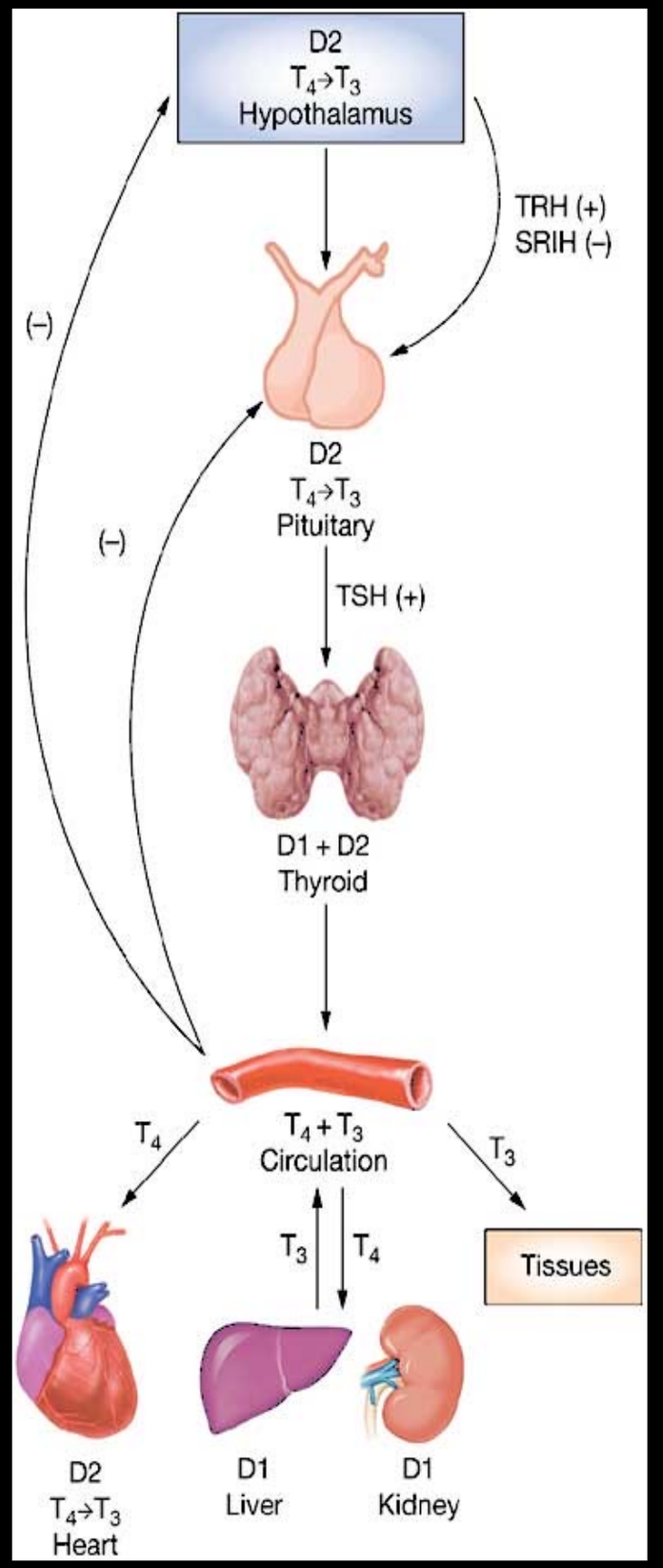


Closed Loop" is a generic term which has no specific meaning

Briefly, a closed-loop system is a system wherein a controller monitors one or multiple variables and adjusts one or more interventions using a feedback process. The term is most often applied to automated systems.

“Physiology” is based on Closed Loop controls

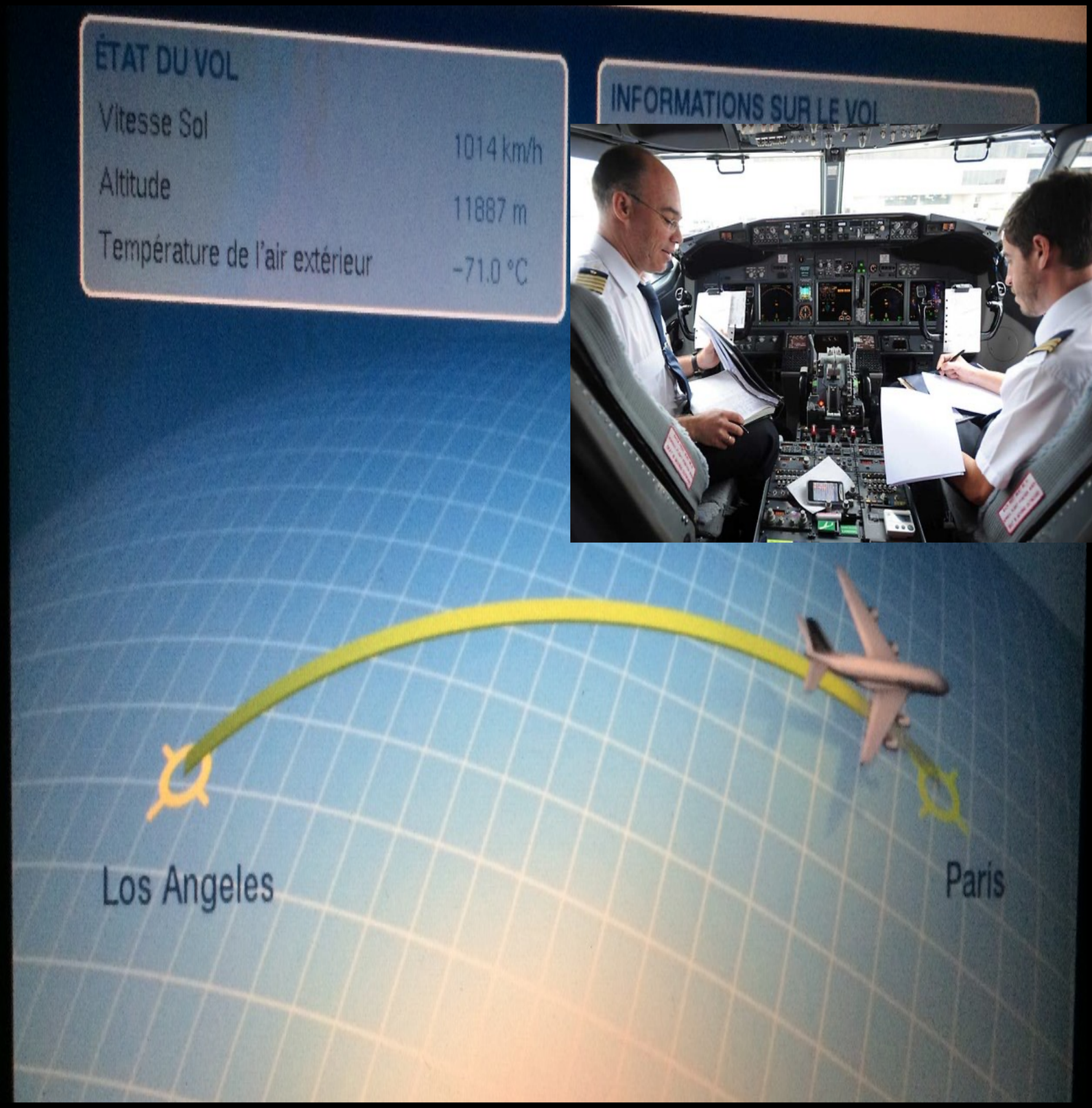


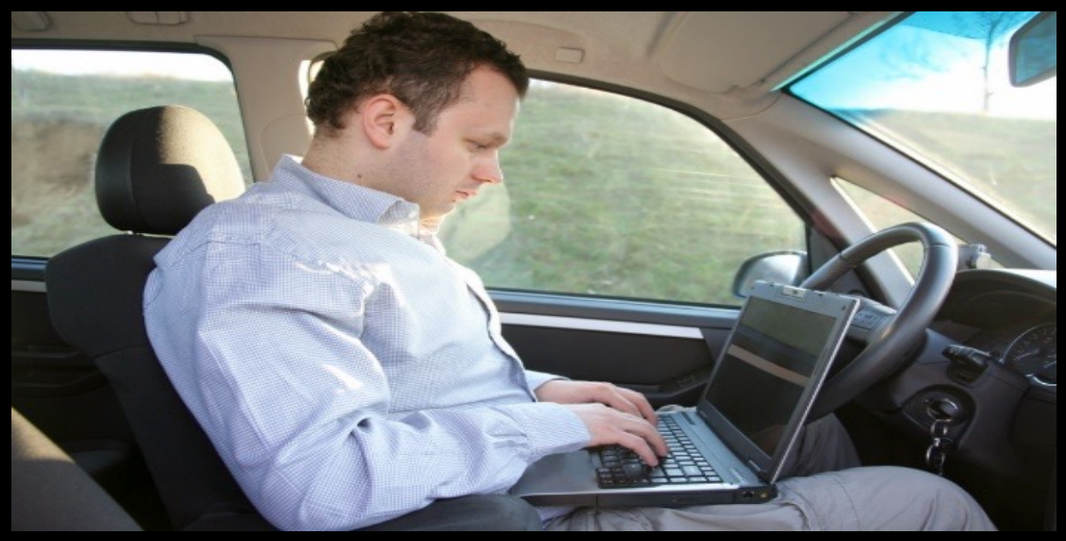


“Life” is based on Closed Loop controls

Thermostat

Cruise control

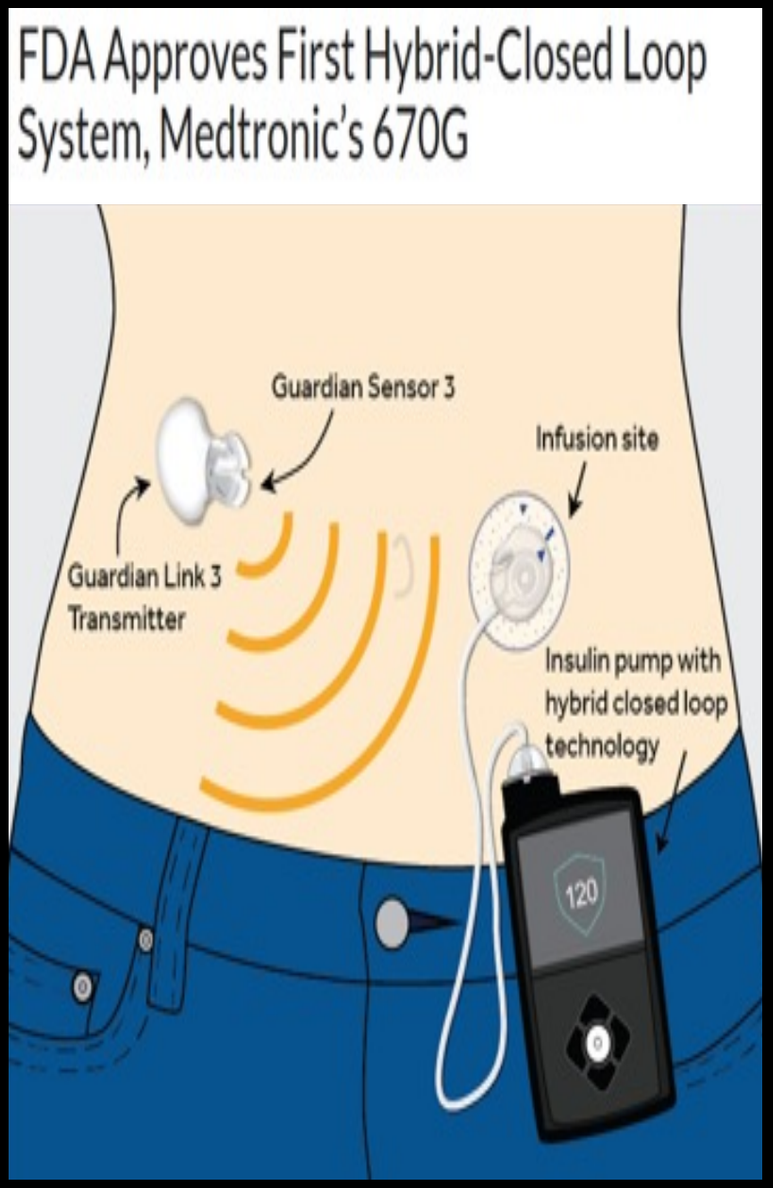


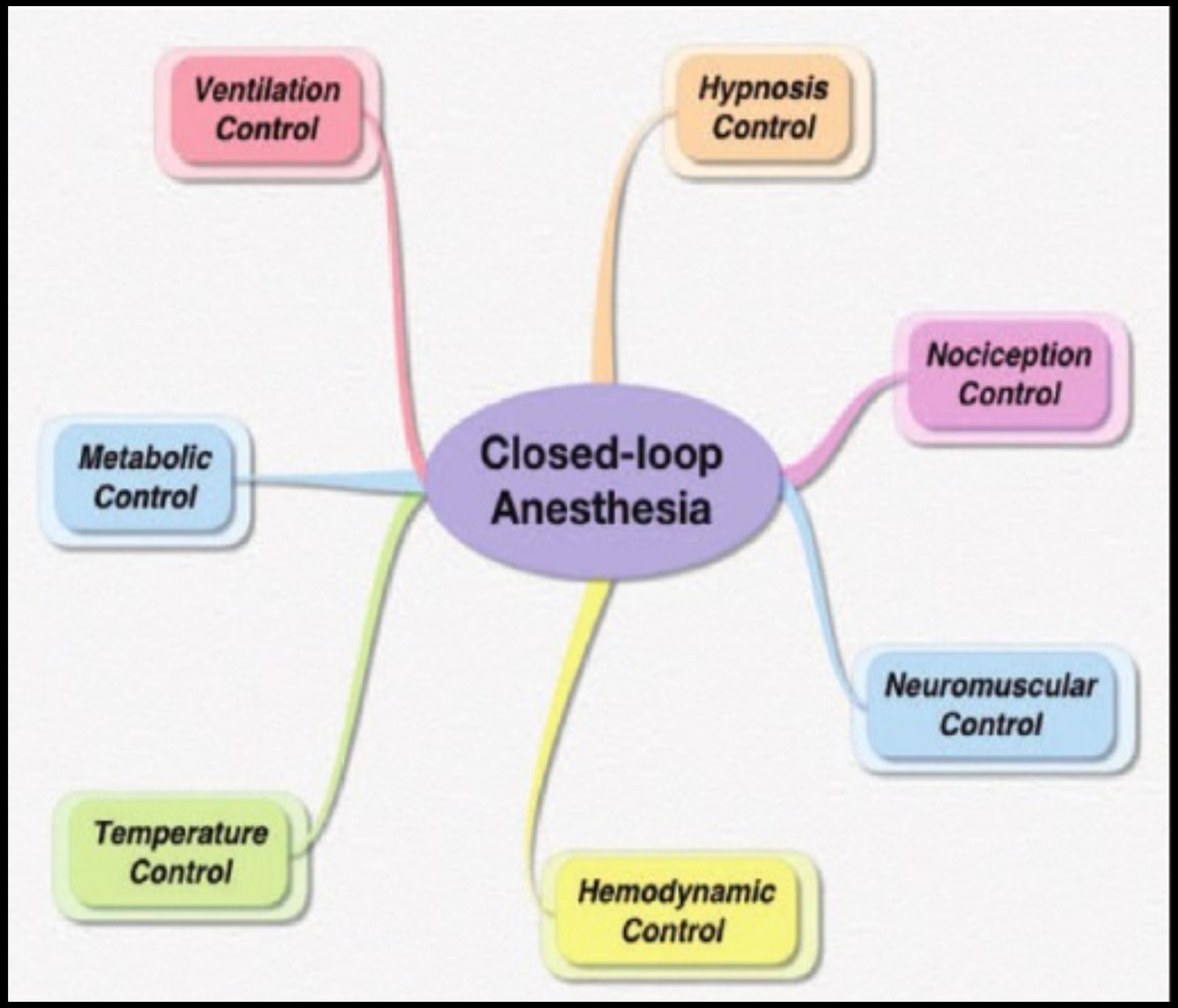


NEWS

Self-driving Audi to drive from California to New York

Closed Loop Systems in Medicine?





Closed-loop drug delivery: A Novel idea?

Trans Am Soc Artif Intern Organs. 1981;27:241-5.

Blood glucose control by closed loop insulin delivery during coronary artery bypass surgery.

Kuntschen F, Galletti PM, Hahn C.

IEEE Trans Biomed Eng. 1981 Jun;28(6):475-9.

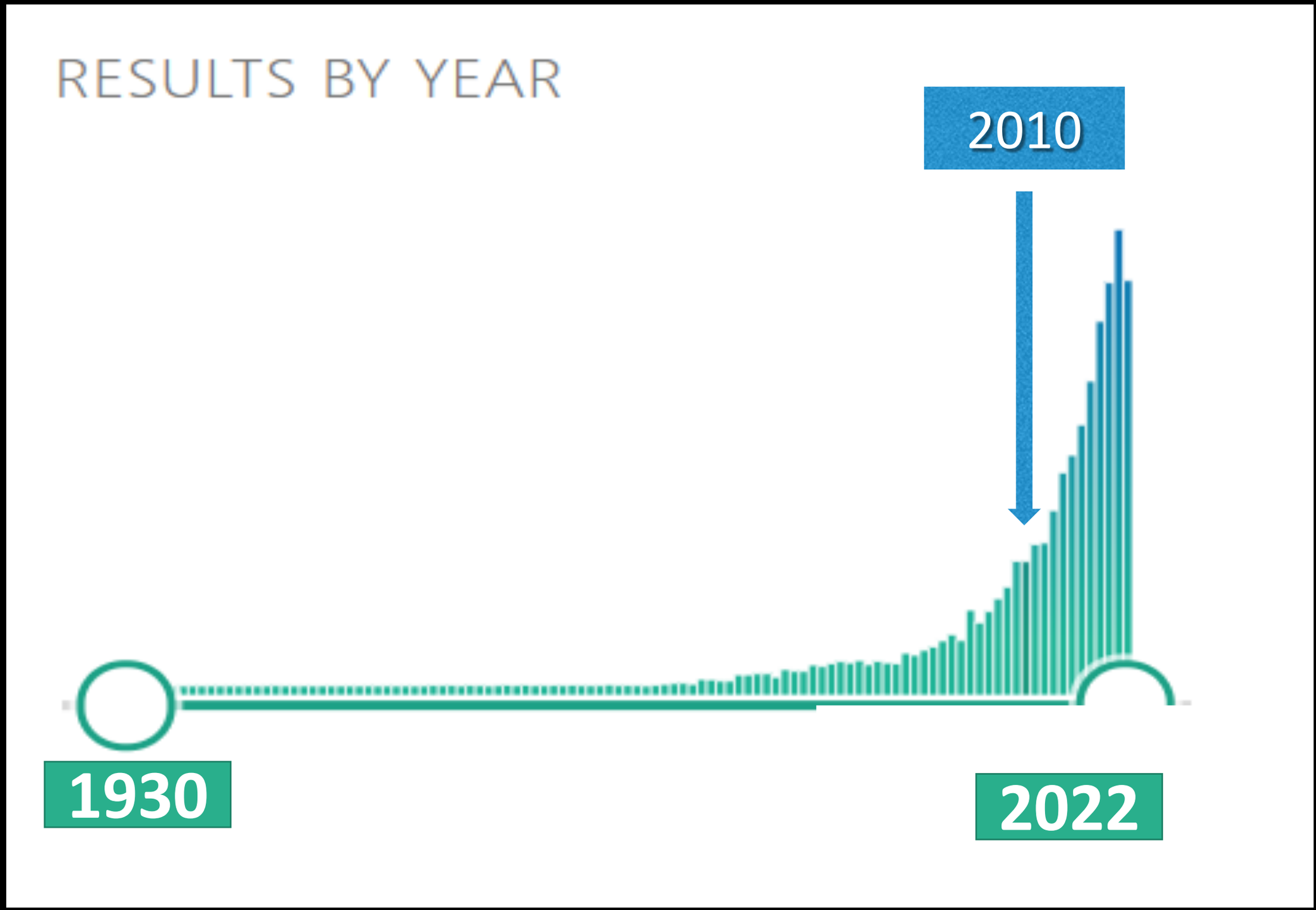
A microcomputer-based fluid infusion system for the resuscitation of burn patients.

Bowman RJ, Westenskow DR.

Crit Care Med. 1982 Dec;10(12):831-4.

The need for closed-loop therapy.

Medically relevant articles with « closed-loop » in title by year



Toolbox Family

1998 2002 2004 2006 2008

Anesthetist can activate the different events of anesthesia and surgery which:

- yield to actions of the different TCI pumps
- start or stop the Matrix of Semi Automated feedback interaction

Between EEG and propofol Ce

Between HR + SBP and remifentanil Ce


TOOLBOX 2004

TOOLBOX Patent ULB

Computer-controlled intravenous drug delivery system

Dec 21, 2004

The present invention relates to a system for computer-aided intravenous delivery of anesthetics and/or other drugs to a patient, wherein said system comprises an Infusion Controller that delivers an amount of drug(s) to a patient; possibly a DataLogger Controller with one or more Sensors adapted so as to be coupled to a patient and to generate signals reflecting one or more health conditions or statuses of the patient; a Communication Controller connected with the infusion pumps and/or monitors; a Session Controller that carries out the modeling of anesthesia procedures and is arranged to run a first procedure and to dynamically adapt said first procedure and/or select and run a second procedure based upon one or more of said sensors' output and/or observation from a physician; a Graphic User Interface to display different views of the system and to accept user input; a set of interfaces used to link the Infusion, Datalogger and Session Controllers to views displayed by the Graphical User Interface; a Processor or Infusion Session Manager that integrates the Graphic User Interface, the Infusion Controller, the DataLogger Controller, the Communication Controller and the Session Controller and that steers drug delivery, wherein the system contains a set of configurable written procedures to steer intravenous anesthetic drug delivery and/or other drug delivery, whereby said procedures have been adapted to the type of surgical action and/or therapy, adapted to the patient's physical condition, and adapted to the type of drugs, tools and theoretical models used. The system of the present invention finds its use among others in intravenous anesthesia (IVA) and in cancer therapy.

Patent number: 9597448
Assignee: Université Libre de Bruxelles (Brussels)
Inventors: Luc Barvais (Wemmel), Eddy Coussaert (Waterloo)

Perioperative Hypotension is

1) FREQUENT
2) MULTIFACTORIAL ETIOLOGY

Vasodilation (anesthetic drugs, deep anesthesia)
Intravascular hypovolemia (bleeding)
Low cardiac output (bradycardia or low stroke volume)
High intraoperative pressure (mechanical ventilation)
Impairment baroreflex regulation

DIFFERENT MECHANISMS

MAP = (CO x SVR) + CVP

DECREASE in SVR and/or CO

Loss of vascular tone

- Sedation
- Anesthetic drugs
- Inflammation
- Spinal anesthesia
- Associated treatment

Abnormal vascular tone

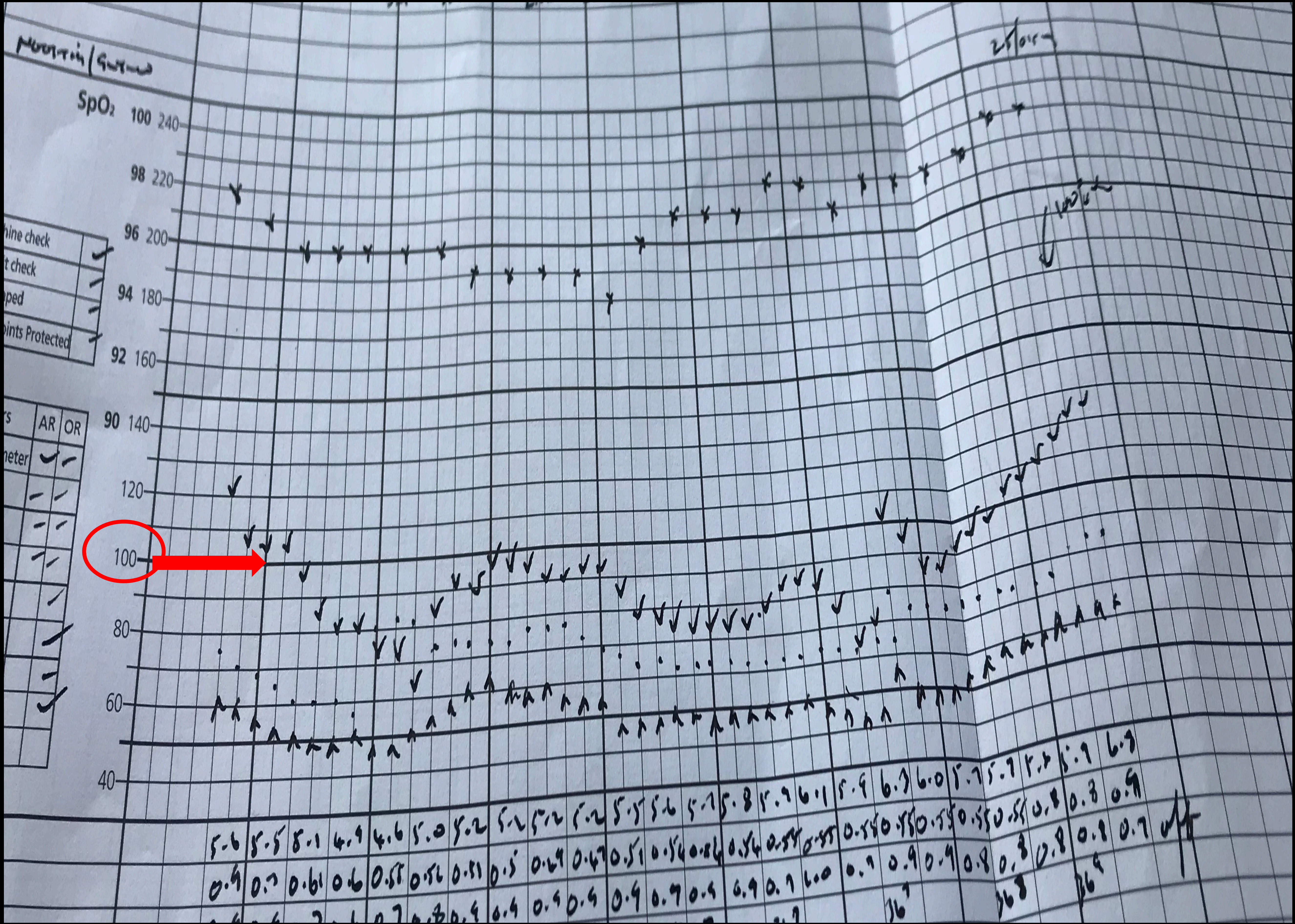
- Age
- Diabete
- Etc…

Cardiac dysfunction

- RV dysfunction
- Pulmonary hypertension
- etc…

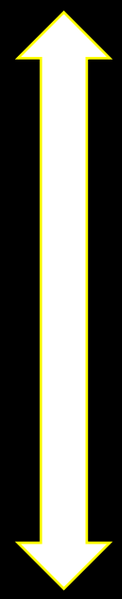
Acute hypovolemia

- Bleeding
- Excessive fluid loss
- Surgical clamping


SpO2
100 240
98 220
96 200
94 180
92 160
90 140
120
100
80
60
40
AR
OR
Joints Protected

Numerous Large Database Analyses

Low Blood Pressure during surgery



Postoperative Organ Injury

(AMI and AKI)

Hypotension and Outcomes

BJA

British Journal of Anaesthesia, 121 (4): 706–721 (2018)
doi: 10.1016/j.bja.2018.04.036

Intensive Care Med (2018) 44:811–822
https://doi.org/10.1007/s00134-018-5224-7

Anaesthesia 2018, 73, 1223-1228

Original Article

REVIEW

018) 68–73

Journal of Clinical Anesthesia 75 (2021) 110516

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CARDIOLOGY

Contents lists available at ScienceDirect

Perioperative Medicine

ORIGINAL CLINICAL RESEARCH REPORT

ELSEVIER

Original Contribution

Association of p
healthcare resou

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FRCA, FRCPC, FFICI
Mitali Stevens, Phar
PhD

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‡Department of Epidemiolog

§Department of Cardiothoracic Surgery, Radboud University, Nijmegen, Nether
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**Department of Clinical Pharmacy, St. Antonius Hospital, Nieuwegein, Nether

K. Maheshwari,[1] A. Turan,[1] G. Mao,[2] D. Yang,[2] A. K. Niaz
A. Kurz[6]

OPEN

Intraoperative Hypotension Is Associated With Adverse Clinical Outcomes After Noncardiac Surgery

Anne Gregory, MD, MSc, FRCPC,* Wolf H. Stapelfeldt, MD,† Ashish K. Khanna, MD, FCCP, FCCM,‡§ Nathan J. Smischney, MD, MSc,‖ Isabel J. Boero, MD, MS,¶ Qinyu Chen, MS,¶ Mitali Stevens, PharmD, BCPS,# and Andrew D. Shaw, MB, FRCPC*,**

Zheng-Liang Ma , Xiao-Ping Gu

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[b] Department of Neurology, The First Affiliated Hospital of Chongqing Medical University, Chongqing Key Laboratory of Neurology, Chongqing 400016, China

IN ICU

Intensive Care Med (2018) 44:857–867
https://doi.org/10.1007/s00134-018-5218-5

ORIGINAL

The relationship between ICU hypotension and in-hospital mortality and morbidity in septic patients

Kamal Maheshwari[1,7*], Brian H. Nathanson[2], Sibyl H. Munson[3], Victor Khangulov[3], Mitali Stevens[4], Hussain Badani[3], Ashish K. Khanna[5] and Daniel I. Sessler[6]

PLOS ONE

RESEARCH ARTICLE

Hypotension and a positive fluid balance are associated with delirium in patients with shock

Duc Nam Nguyen[1]*, Luc Huyghens[1], Jose Parra[2], Johan Schiettecatte[3], Johan Smitz[3], Jean-Louis Vincent[4]

Observational Study > Anesth Analg. 2021 May 1;132(5):1410-1420.
doi: 10.1213/ANE.0000000000005374.

Postoperative Hypotension and Adverse Clinical Outcomes in Patients Without Intraoperative Hypotension, After Noncardiac Surgery

Ashish K Khanna [1 2], Andrew D Shaw [3 4], Wolf H Stapelfeldt [5], Isabel J Boero [6], Qinyu Chen, Mitali Stevens [7], Anne Gregory [3], Nathan J Smischney [8]

Vincent *et al. Ann. Intensive Care* (2018) 8:107
https://doi.org/10.1186/s13613-018-0448-9

Annals of Intensive Care

RESEARCH **Open Access**

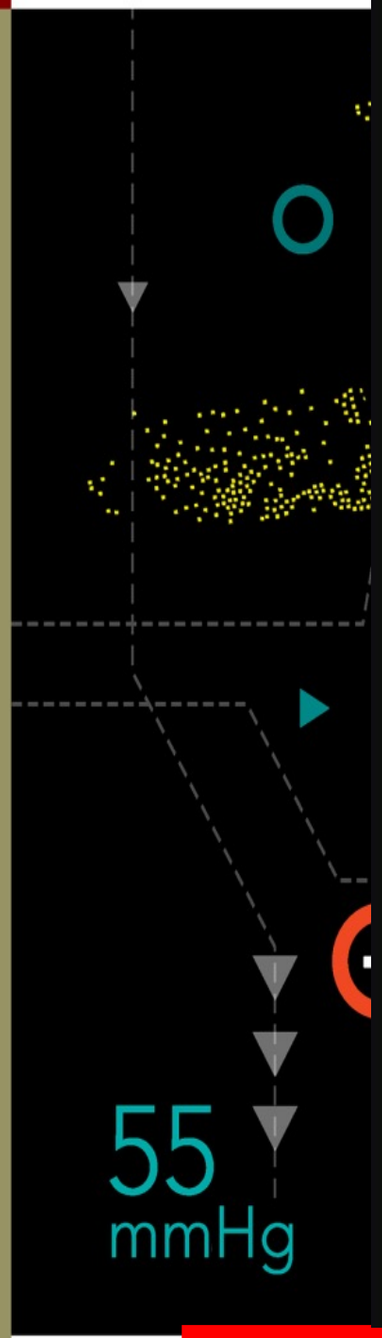
Mean arterial pressure and mortality in patients with distributive shock: a retrospective analysis of the MIMIC-III database

Jean-Louis Vincent[1*], Nathan D. Nielsen[2], Nathan I. Shapiro[3], Margaret E. Gerbasi[4], Aaron Grossman[5], Robin Doroff[5], Feng Zeng[6], Paul J. Young[7] and James A. Russell[8]

Association Between Mean Arterial Pressure and Acute Kidney Injury and a Composite of Myocardial Injury and Mortality in Postoperative Critically Ill Patients: A Retrospective Cohort Analysis

Ashish K. Khanna, MD, FCCP, FCCM[1,2]; Kamal Maheshwari, MD, MPH[3]; Guangmei Mao, MS[3,4]; Liu Liu, MS[3,4]; Silvia E. Perez-Protto, MD[3]; Praneeta Chodavarapu, MD[3]; Yehoshua N. Schacham, MD[3]; Daniel I. Sessler, MD[3]

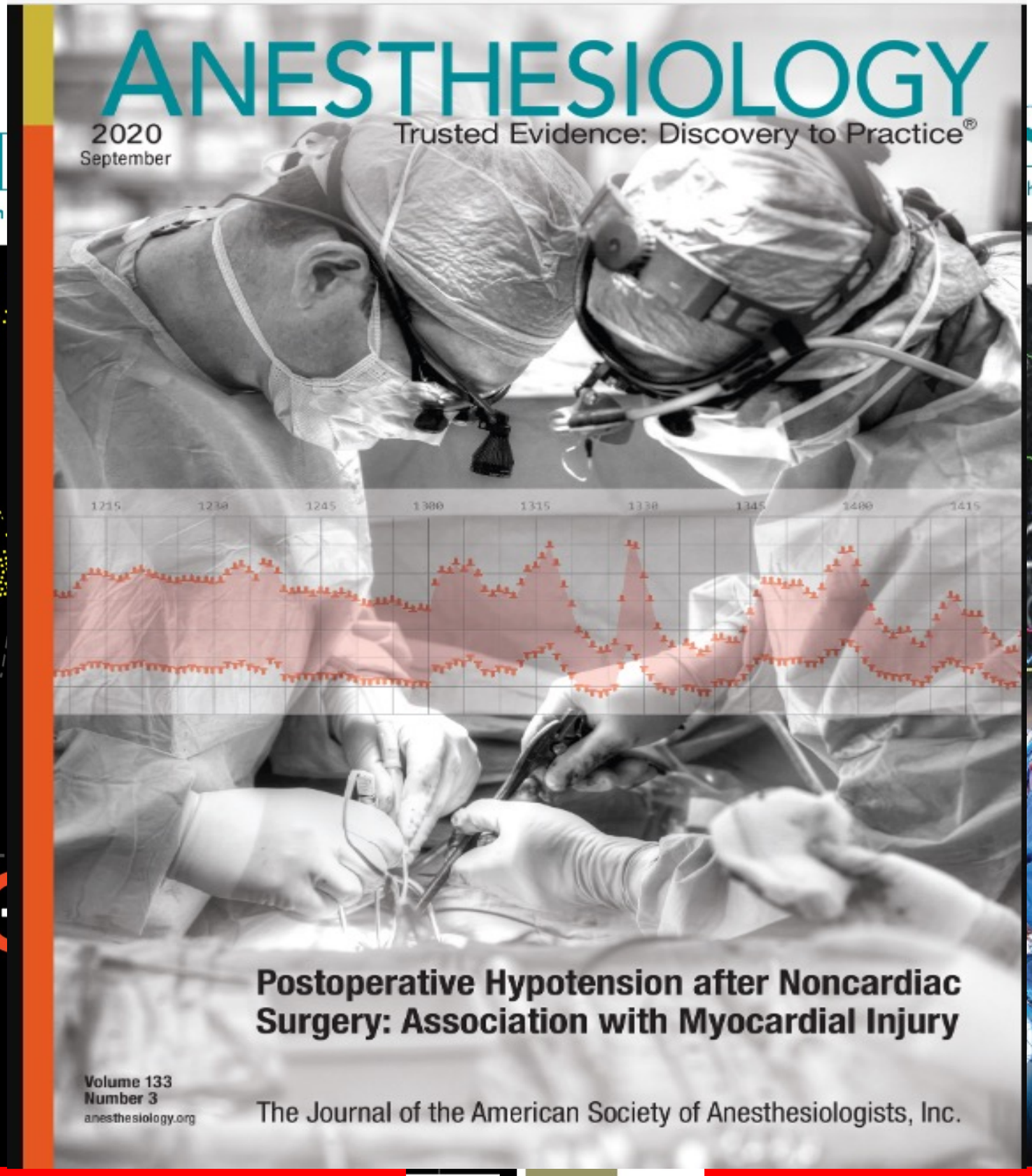
***Crit Care Med* 2019**



ANEST

The Journal of the American

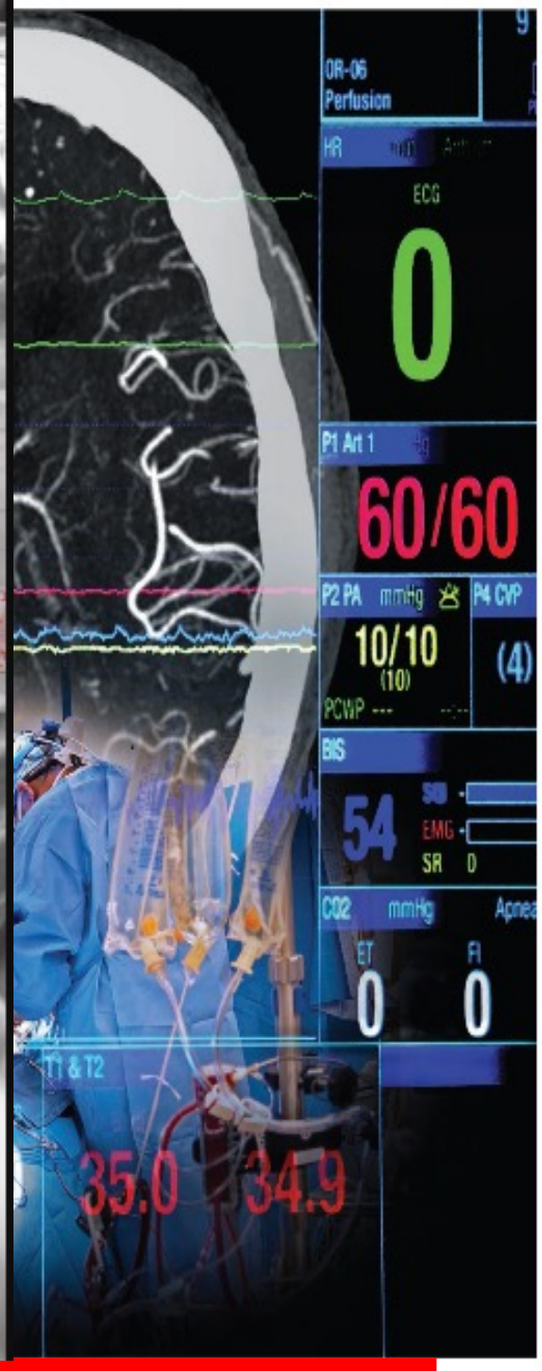
Intraoperative Hypotension and Acute Kidney Injury



September 2018
Volume 129, Number 3
ISSN 0003-3022

SIOLOGY

hesiologists, Inc. • anesthesiology.org



Low Mean Arterial Pressure during Cardiopulmonary Bypass Is Associated with an Increased Risk of Stroke

Relationship between Intraoperative Mean Arterial Pressure and Clinical Outcomes after Noncardiac Surgery

Toward an Empirical Definition of Hypotension

Michael Walsh, M.D.,* Philip J. Devereaux, M.D., Ph.D.,† Amit X. Garg, M.D., Ph.D.,‡ Andrea Kurz, M.D.,§ Alparslan Turan, M.D.,‖ Reitze N. Rodseth, M.D.,# Jacek Cywinski, M.D.,** Lehana Thabane, Ph.D.,†† Daniel I. Sessler, M.D.‡‡

Anesthesiology 2013; 119:507-15

33,330 non-cardiac surgeries at the Cleveland Clinic, Ohio

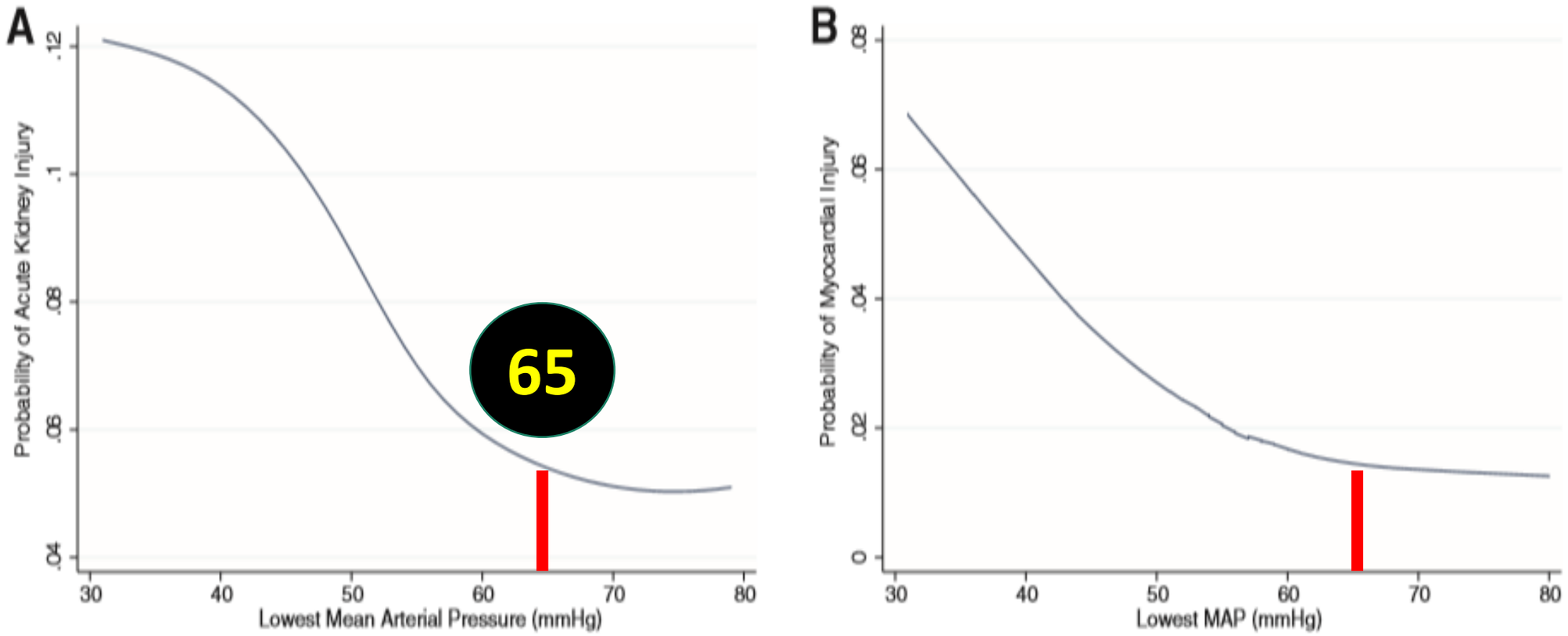
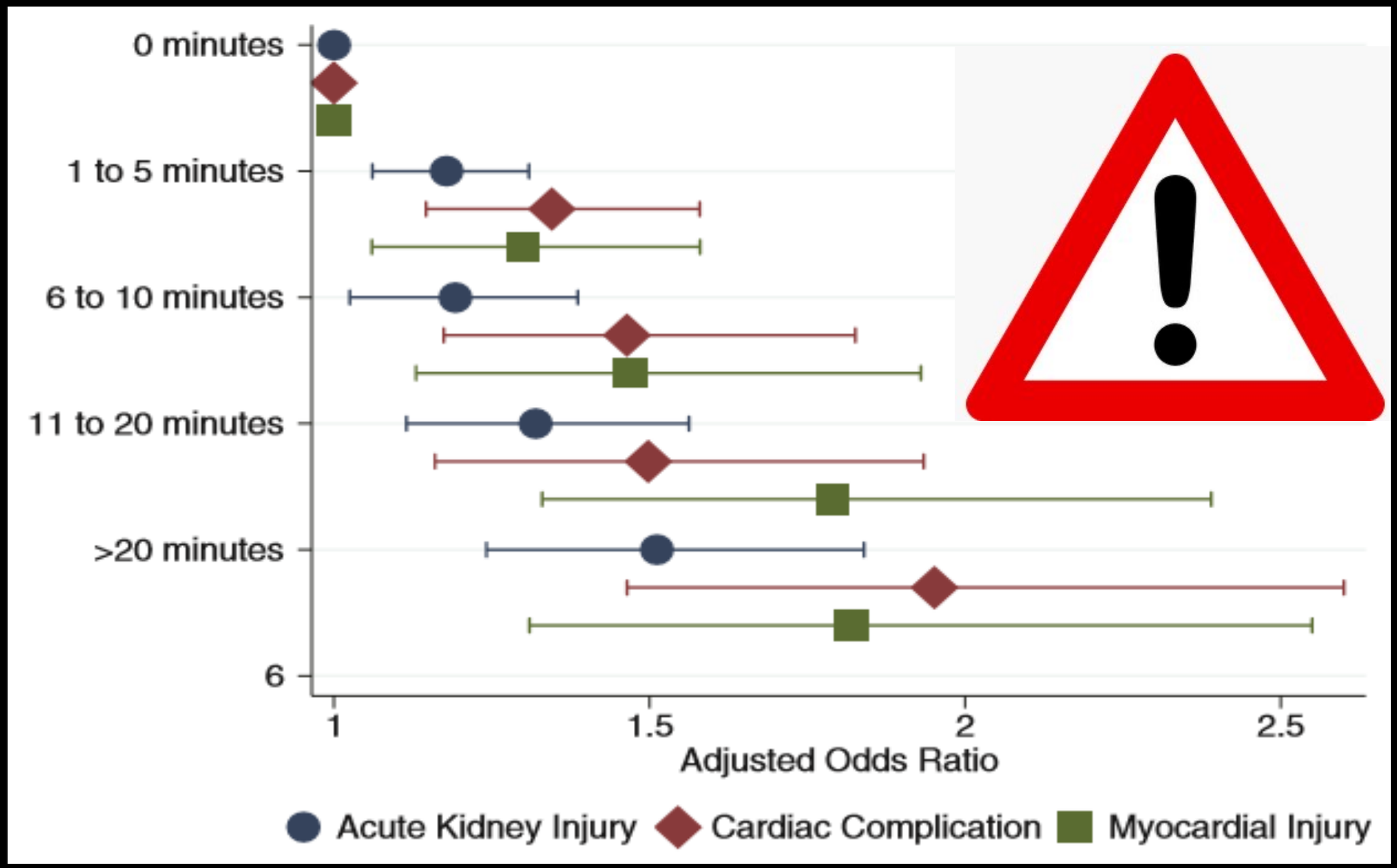


Fig. 3. Predicted probability of (*A*) acute kidney injury and (*B*) myocardial injury by lowest mean arterial pressure (MAP) experienced during surgery.

AKI and MI by lowest MAP

INJURY= Minutes MAP < 55 mmHg



Time spent with a MAP < 55 mmHg during noncardiac surgery is independently associated with an increased risk of AKI & MI

Notably, any amount of time at a MAP < 55 mmHg was associated with adverse outcomes

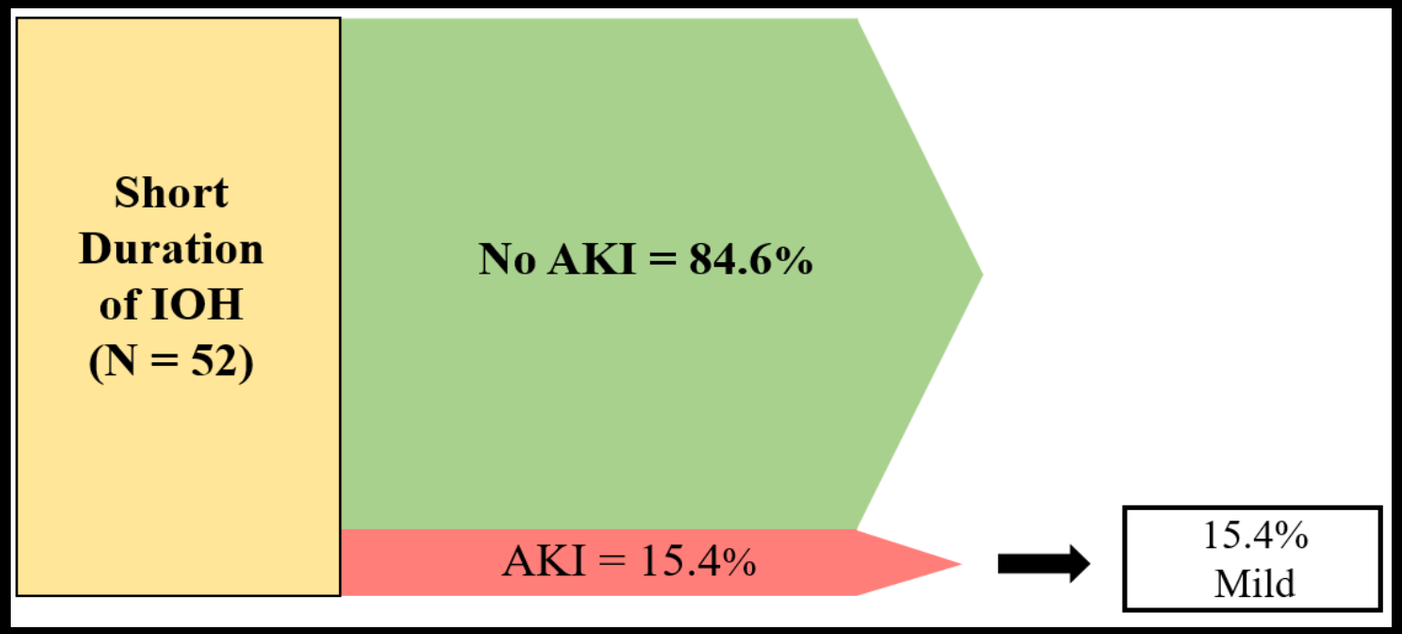
Joosten *et al. BMC Anesthesiology* (2021) 21:12
https://doi.org/10.1186/s12871-020-01228-y

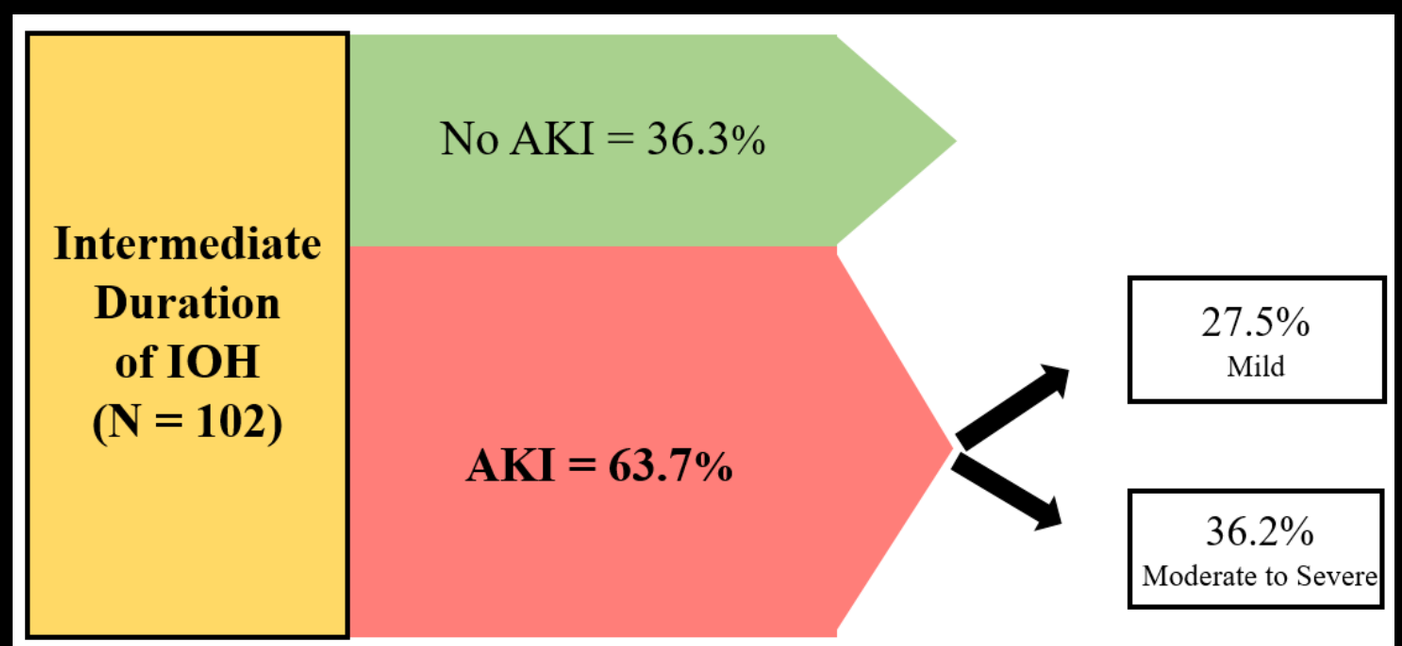
BMC Anesthesiology

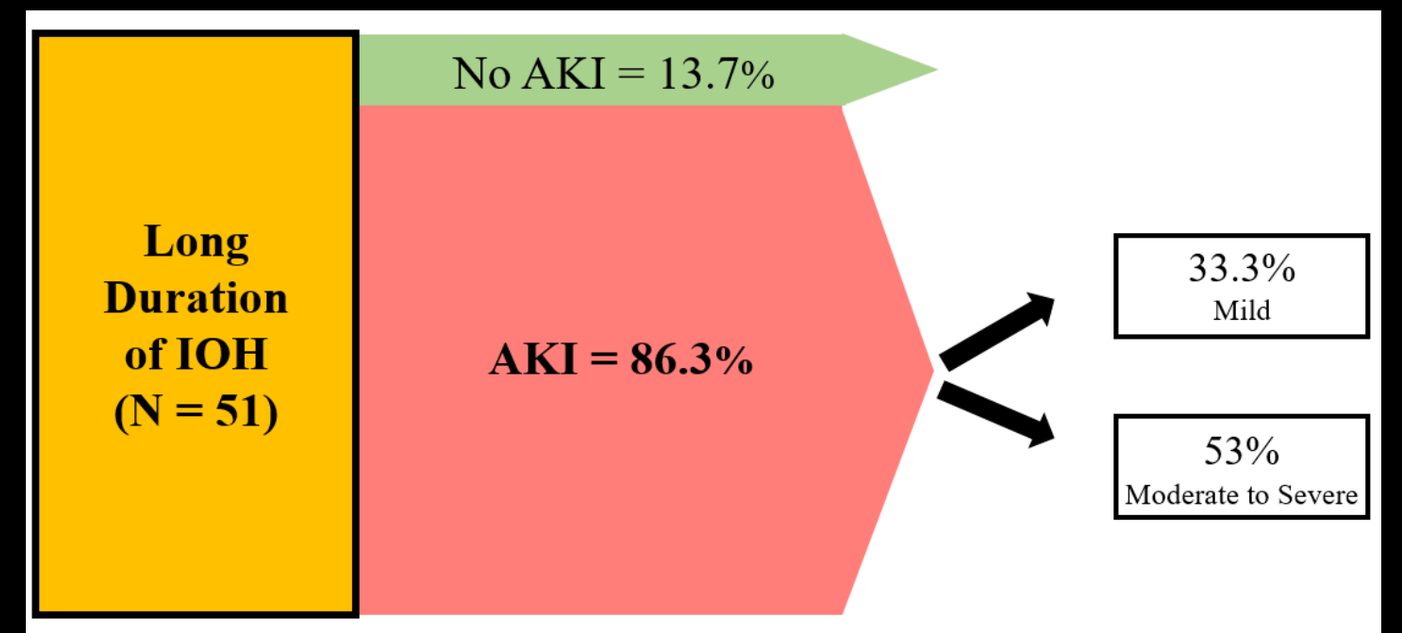
RESEARCH ARTICLE Open Access

Intraoperative hypotension during liver transplant surgery is associated with postoperative acute kidney injury: a historical cohort study

Joosten et al, BMC ANESTHESIOLOGY 2021


Short Duration of IOH (N = 52)
No AKI = 84.6%
AKI = 15.4%
15.4% Mild


Intermediate Duration of IOH (N = 102)
No AKI = 36.3%
AKI = 63.7%
27.5% Mild
36.2% Moderate to Severe


Long Duration of IOH (N = 51)
No AKI = 13.7%
AKI = 86.3%
33.3% Mild
53% Moderate to Severe

1) Hypnosis drugs administration

Anesthesiology. 2012 Feb;116(2):286-95. doi: 10.1097/ALN.0b013e318242ad4f.

Feasibility of closed-loop titration of propofol and remifentanil guided by the spectral M-Entropy monitor.

Liu N[1], Le Guen M, Benabbes-Lambert F, Chazot T, Trillat B, Sessler DI, Fischler M.

J Clin Monit Comput. 2019 Jul 20. doi: 10.1007/s10877-019-00360-6. [Epub ahead of print]

Behavior of a dual closed-loop controller of propofol and remifentanil guided by the bispectral index for postoperative sedation of adult cardiac surgery patients: a preliminary open study.

Squara P[1], Chazot T[2,3], Auboin G[2,3], Fischler M[4,5], Dreyfus JF[6], Le Guen M[2,3], Liu N[2,3,7].

Minerva Anestesiol. 2018 Apr;84(4):437-446. doi: 10.23736/S0375-9393.17.11915-2. Epub 2017 Dec 13.

Effects of closed-loop intravenous anesthesia guided by Bispectral Index in adult patients on emergence delirium: a randomized controlled study.

Cotoia A[1], Mirabella L[2], Beck R[2], Matrella P[2], Assenzo V[3,4,5], Chazot T[3,4], Cinnella G[2], Liu N[3,4,5], Dambrosio M[2].

Intensive Care Med. 2013 Mar;39(3):454-62. doi: 10.1007/s00134-012-2762-2. Epub 2012 Dec 6.

Automated sedation outperforms manual administration of propofol and remifentanil in critically ill patients with deep sedation: a randomized phase II trial.

Le Guen M[1], Liu N, Bourgeois E, Chazot T, Sessler DI, Rouby JJ, Fischler M.

Anesth Analg. 2011 Mar;112(3):546-57. doi: 10.1213/ANE.0b013e318205680b. Epub 2011 Jan 13.

Closed-loop coadministration of propofol and remifentanil guided by bispectral index: a randomized multicenter study.

Liu N[1], Chazot T, Hamada S, Landais A, Boichut N, Dussaussoy C, Trillat B, Beydon L, Samain E, Sessler DI, Fischler M.

Anesthesiology. 2006 Apr;104(4):686-95.

Titration of propofol for anesthetic induction and maintenance guided by the bispectral index: closed-loop versus manual control: a prospective, randomized, multicenter study.

Liu N[1], Chazot T, Genty A, Landais A, Restoux A, McGee K, Laloë PA, Trillat B, Barvais L, Fischler M.

ANESTHESIA & ANALGESIA®

SYSTEMATIC REVIEW ARTICLE

Closed-Loop Delivery Systems Versus Manually Controlled Administration of Total IV Anesthesia: A Meta-analysis of Randomized Clinical Trials

Laura Pasin, MD, Pasquale Nardelli, MD, Margherita Pintaudi, MD, Massimiliano Greco, MD, Massimo Zambon, MD, Luca Cabrini, MD, and Alberto Zangrillo, MD

META-ANALYSIS

Anesthetic Clinical Pharmacology

Anesthetic Clinical Pharmacology Section Editor: **Ken B. Johnson**
Preclinical Pharmacology Section Editor: **Markus W. Hollmann**

SYSTEMATIC REVIEW ARTICLE

Clinical Performance and Safety of Closed-Loop Systems: A Systematic Review and Meta-analysis of Randomized Controlled Trials

Etrusca Brogi, MD,* Shantale Cyr, PhD,† Roy Kazan, MD, MSc,‡ Francesco Giunta, MD,* and Thomas M. Hemmerling, MSc, MD, DEAA†‡

Closed-loop systems (CLS), when compared to human management:

1) Better maintains a given target within a selected range

2) Decreases overshooting or undershooting of a given target

Potential benefits of closed-loop systems

- Automation of previously manual tasks
- Improvement in stability of the controlled parameters
- Monitor and analyze more frequently
- The closed-loop is not distractible from its task
- Its algorithm is perfectly repeatable
- Allow anesthesiologist to focus on higher clinical tasks and decisions
- Areas left for human being: Elaboration, Creation and management of unique situation

On the market

Concert CL

Neurowave CL

Medsteer, Paris

2) Analgesic drug administration

Conf Proc IEEE Eng Med Biol Soc. 2018 Jul;2018:506-509. doi: 10.1109/EMBC.2018.8512330.

Closed-loop administration of analgesic drugs based on heart rate variability analysis.

De Jonckheere J, Jeanne M, Keribedj A, Delecroix M, Logier R.

3) Fluid administration

BJA Advance Access published January 13, 2015

British Journal of Anaesthesia Page 1 of 10
doi:10.1093/bja/aeu452

BJA

Variability in practice and factors predictive of total crystalloid administration during abdominal surgery: retrospective two-centre analysis

M. Lilot[1,2], J. M. Ehrenfeld[3], C. Lee[1], B. Harrington[1], M. Cannesson[1] and J. Rinehart[1*]

Perioperative Fluid Utilization Variability and Association With Outcomes

Considerations for Enhanced Recovery Efforts in Sample US Surgical Populations

British Journal of Anaesthesia 114 (5): 717–21 (2015)
Advance Access publication 19 March 2015 · doi:10.1093/bja/aev067

Perioperative fluid management: science, art or random chaos?

G. Minto[1,2] and M. G. Mythen[3,4,*]

Messina *et al. Crit Care* (2021) 25:43
https://doi.org/10.1186/s13054-021-03464-1

Critical Care

RESEARCH Open Access

Association between perioperative fluid administration and postoperative outcomes: a 20-year systematic review and a meta-analysis of randomized goal-directed trials in major visceral/noncardiac surgery

Antonio Messina[1,2*], Chiara Robba[3,4], Lorenzo Calabrò[1], Daniel Zambelli[1], Francesca Iannuzzi[4], Edoardo Molinari[4], Silvia Scarano[4], Denise Battaglini[4], Marta Baggiani[5], Giacomo De Mattei[6], Laura Saderi[7], Giovanni Sotgiu[7], Paolo Pelosi[3,4] and Maurizio Cecconi[1,2]

Conclusions

GDT strategy reduces postoperative complications

Effect of a Perioperative, Cardiac Output–Guided Hemodynamic Therapy Algorithm on Outcomes Following Major Gastrointestinal Surgery

A Randomized Clinical Trial and Systematic Review

-Multicenter RCT
➔largest study in the field
-734 medium to high-risk patients
-Primary outcome: composite of postoperative complications & mortality

Editorial

Perioperative goal directed therapy: Evidence and compliance are two sides of the same coin

A. Joosten[a,b], J. Rinehart[a], M. Cannesson[a,]

Mortality at 180 days	**7.7%**	**11.6%**	**0.08**

assumed to experience the same outcome as if they had been allocated to the alternative group (RR, 0.80; 95% CI, 0.61-0.99; *P* = .04).

JAMA®

Compliance is a huge problem

Emerg Med J. 2009 Jan;26(1):23-7. doi: 10.1136/emj.2008.058073.

Protocol compliance and time management in blunt trauma resuscitation.

Spanjersberg WR[1], Bergs EA, Mushkudiani N, Klimek M, Schipper IB.

→ Compliance = 42%

Compliance with evidence-based clinical management guidelines in bleeding trauma patients

A. Godier[1,2], M. Bacus[3], E. Kipnis[3], B. Tavernier[3], A. Guidat[3,4], A. Rauch[5,6], E. Drumez[7], S. Susen[5,6] and D. Garrigue-Huet[3,8,*]

→ Compliance = 40%

Diabetes Technol Ther. 2011 Mar;13(3):343-9. doi: 10.1089/dia.2010.0100. Epub 2011 Feb 3.

Impact of an alerting clinical decision support system for glucose control on protocol compliance and glycemic control in the intensive cardiac care unit.

Lipton JA[1], Barendse RJ, Schinkel AF, Akkerhuis KM, Simoons ML, Sijbrands EJ.

→ Compliance = 52%

Cannesson *et al. Critical Care* (2015) 19:261
DOI 10.1186/s13054-015-0945-2

CRITICAL CARE

RESEARCH Open Access

Perioperative goal-directed therapy and postoperative outcomes in patients undergoing high-risk abdominal surgery: a historical-prospective, comparative effectiveness study

Maxime Cannesson[1,2*], Davinder Ramsingh[1], Joseph Rinehart[1], Aram Demirjian[3], Trung Vu[1], Shermeen Vakharia[1], David Imagawa[3], Zhaoxia Yu[4], Sheldon Greenfield[2] and Zeev Kain[1]

→ Compliance = 62%

Compliance is linked to poor patient's outcomes

Adherence to the Enhanced Recovery After Surgery Protocol and Outcomes After Colorectal Cancer Surgery

Ulf O. Gustafsson, MD, PhD; Jonatan Hausel, MD; Anders Thorell, MD, PhD; Olle Ljungqvist, MD, PhD; Mattias Soop, MD, PhD; Jonas Nygren, MD, PhD; for the Enhanced Recovery After Surgery Study Group

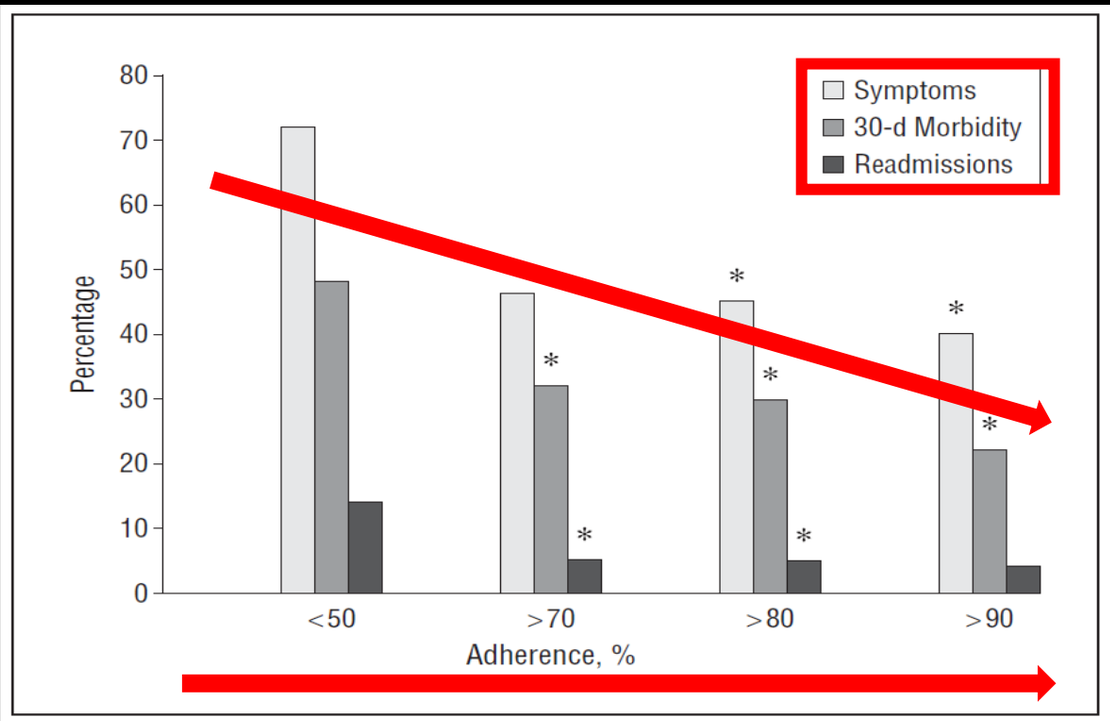
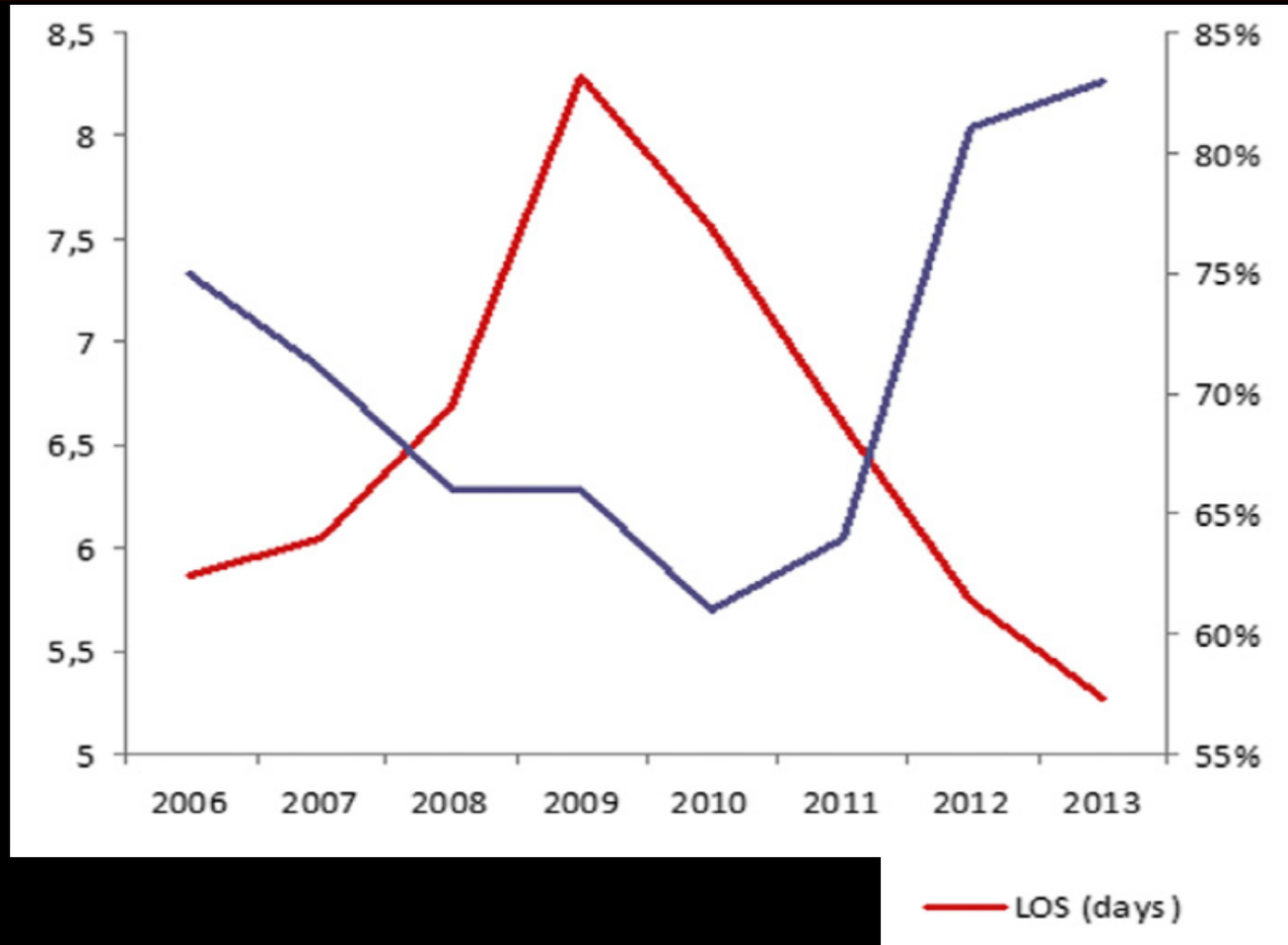


Figure 3. Association between adherence to the enhanced recovery after surgery protocol and postoperative outcomes. *Statistically significant at $P < .05$.

Eight years of experience with Enhanced Recovery After Surgery in patients with colon cancer: Impact of measures to improve adherence

Nathalie Bakker, MD,[a,b,c] Hamit Cakir, MD,[a] H. J. Doodeman, MSc,[a,b] *and* A. P. J. Houdijk, MD, PhD,[a,b,c] *Alkmaar and Amsterdam, The Netherlands*



BJA

British Journal of Anaesthesia, 115 (4): 560–8 (2015)

doi: 10.1093/bja/aev105
Advance Access Publication Date: 29 April 2015
Clinical Practice

CLINICAL PRACTICE

Enhanced recovery from surgery in the UK: an audit of the enhanced recovery partnership programme 2009–2012†

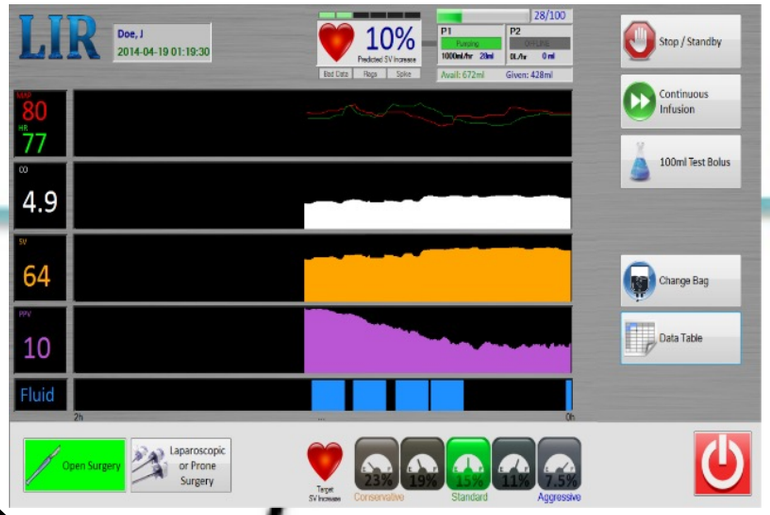
J. C. Simpson[1], S. R. Moonesinghe[1,2], M. P. W. Grocott[1,2,3], M. Kuper[4], A. McMeeking[5], C. M. Oliver[1,2], M. J. Galsworthy[1,2], and M. G. Mythen[1,*] on behalf of the National Enhanced Recovery Partnership Advisory Board‡

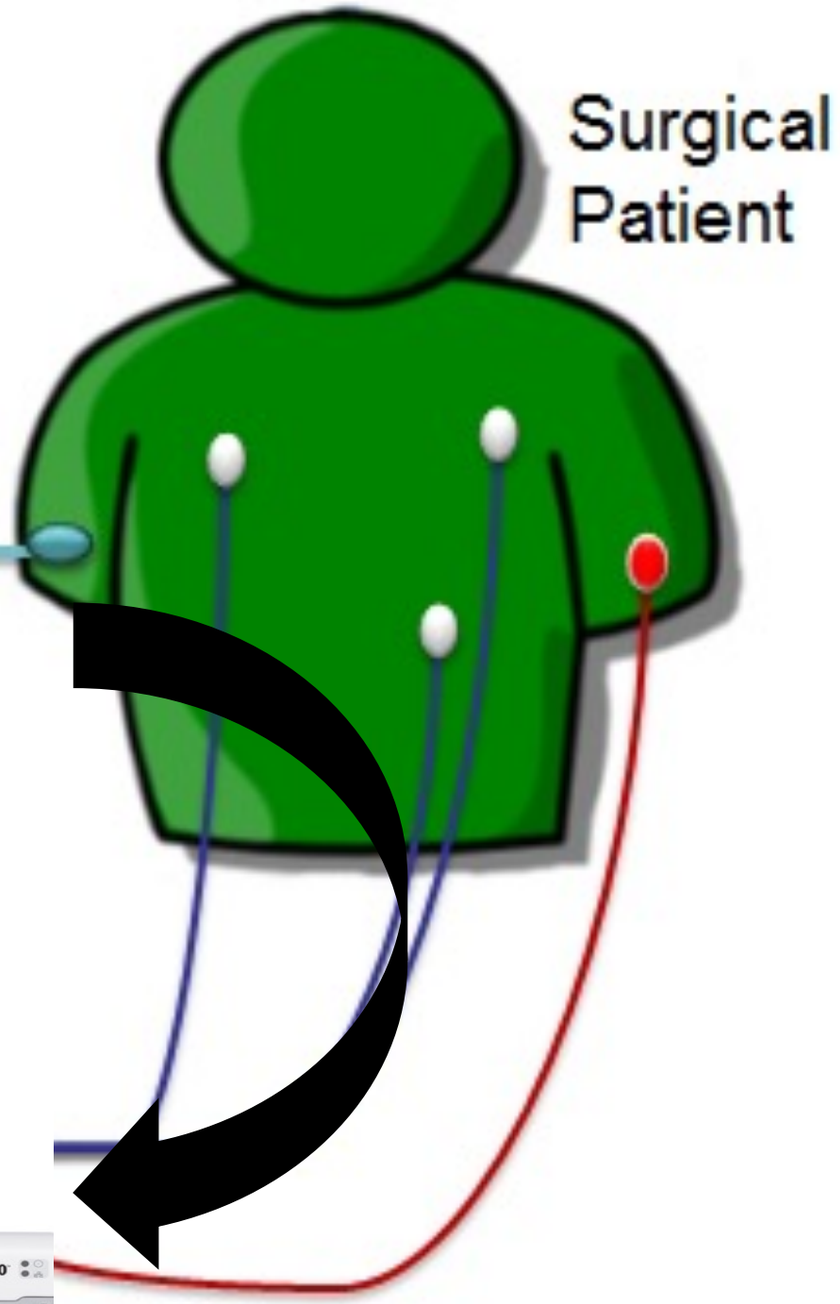
Need > 80% compliance with pathways to see most improved outcomes

Department of Anesthesiology & Perioperative Care
School of Medicine
University of California • Irvine

Q core Sapphire Pump

Intelligent pump automatically runs at the optimal fluid rate





Standard IV Fluids

SIRONIS®
Intelligent Medical Technologies

Standard Monitors

Extensive pre-clinical evaluation from 2011-2013

Society for Technology in Anesthesia

Section Editor: Maxime Cannesson

Closed-Loop Fluid Resuscitation: Robustness Against Weight and Cardiac Contractility Variations

Joseph Rinehart, MD,* Christine Lee, BS,* Maxime Cannesson, MD, PhD,* and Guy Dumont, PhD†

Rinehart *et al. Critical Care* 2011, **15**:R278
http://ccforum.com/content/15/6/R278

CRITICAL CARE

RESEARCH Open Access

Evaluation of a novel closed-loop fluid-administration system based on dynamic predictors of fluid responsiveness: an *in silico* simulation study

Joseph Rinehart[1], Brenton Alexander[1], Yannick Le Manach[2,3], Christoph K Hofer[4], Benoit Tavernier[5], Zeev N Kain[1] and Maxime Cannesson[1*]

Journal of Cardiothoracic and Vascular Anesthesia, Vol 26, No 5 (October), 2012: pp 933-939

Intraoperative Stroke Volume Optimization Using Stroke Volume, Arterial Pressure, and Heart Rate: Closed-Loop (Learning Intravenous Resuscitator) Versus Anesthesiologists

Joseph Rinehart, MD, Elena Chung, MD, Cecilia Canales, MPH, and Maxime Cannesson, MD, PhD

Closed-Loop Fluid Administration Compared to Anesthesiologist Management for Hemodynamic Optimization and Resuscitation During Surgery: An In Vivo Study

Joseph Rinehart, Christine Lee, Cecila Canales, Allen Kong, Zeev Kain, Maxime Cannesson
Anesthesia Analgesia 2013

Ann Fr Anesth Reanim. 2014 Mar;33(3):e35-41. doi: 10.1016/j.annfar.2013.11.016. Epub 2013 Dec 27.

First closed-loop goal directed fluid therapy during surgery: a pilot study.

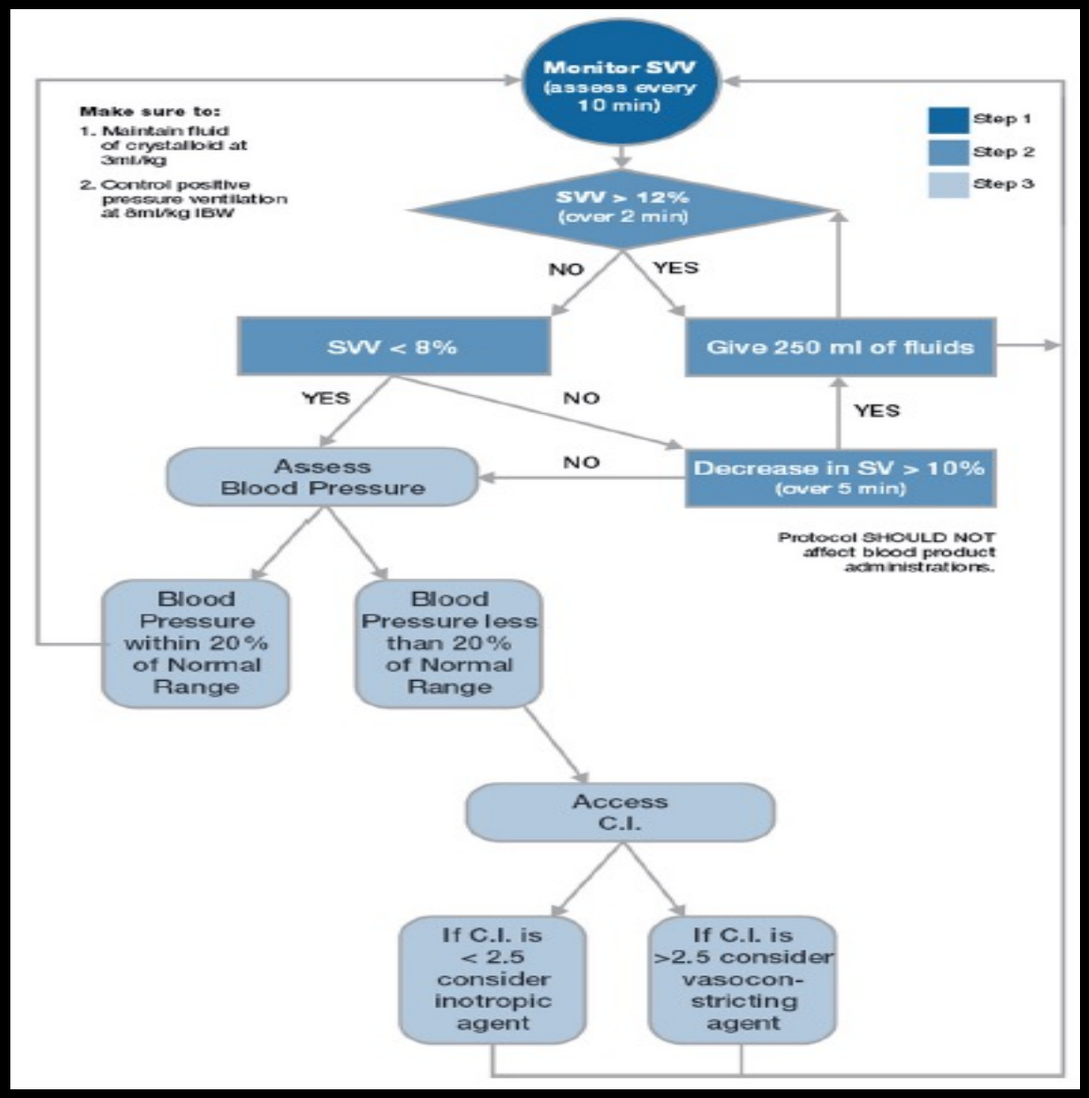
Rinehart J[1], Le Manach Y[2], Douiri H[3], Lee C[1], Lilot M[1], Le K[1], Canales C[1], Cannesson M[4].

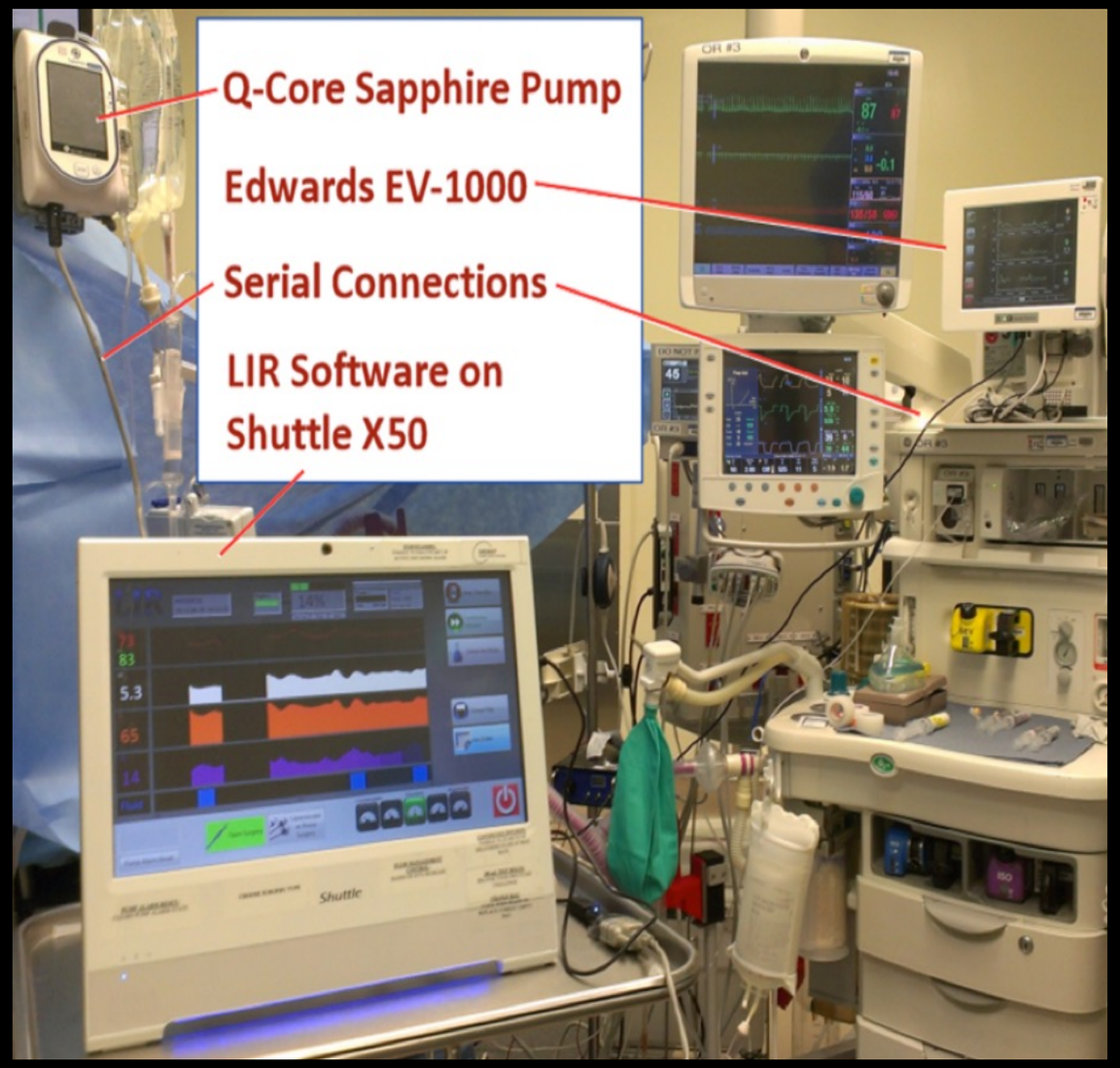
Rinehart *et al. Critical Care* (2015) 19:94
DOI 10.1186/s13054-015-0827-7

CRITICAL CARE

RESEARCH Open Access

Closed-loop assisted versus manual goal-directed fluid therapy during high-risk abdominal surgery: a case–control study with propensity matching





RINEHART et al, Crit Care 2015


STOP
56
VES
PVP
VTDG
PEG
EPEV
5
VVE
70
FP
3.9
DC
RVS
66
PAM
ScvO2
3.9
DC
2.7
IC
38
VESI
5
VVE

BRUGMANN HOSPITAL

ERASME HOSPITAL

The primary outcome: compliance to GDFT protocol

= percentage of case time where SVV was ≤ 12%

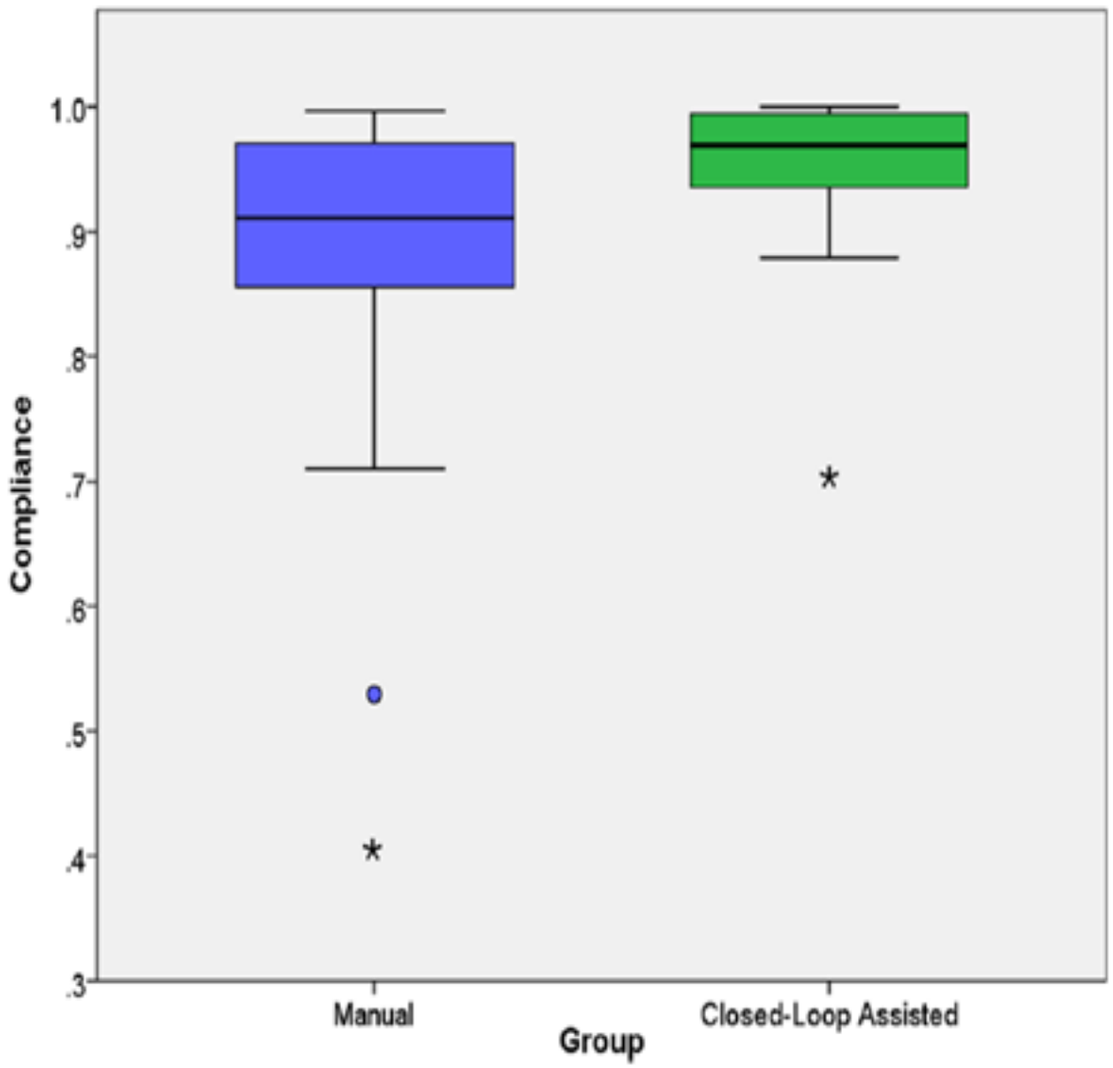


Figure 4 Goal-directed fluid therapy compliance by group. Box plots for the manual and closed-loop assisted groups, including outliers, are shown. The closed-loop assistance not only improved mean compliance to goal-directed fluid therapy (GDT) principles but also substantially reduced the variability in compliance within the group (manual group compliance standard deviation (SD) =14%, closed-loop group compliance SD =6%). Asterisks represent outliers, dot represent extreme outliers.

➔ This system may help providers maintain high compliance to GDFT protocols.

EJA

Eur J Anaesthesiol 2018; **35:**1–9

ORIGINAL ARTICLE

Implementation of closed-loop-assisted intra-operative goal-directed fluid therapy during major abdominal surgery

A case–control study with propensity matching

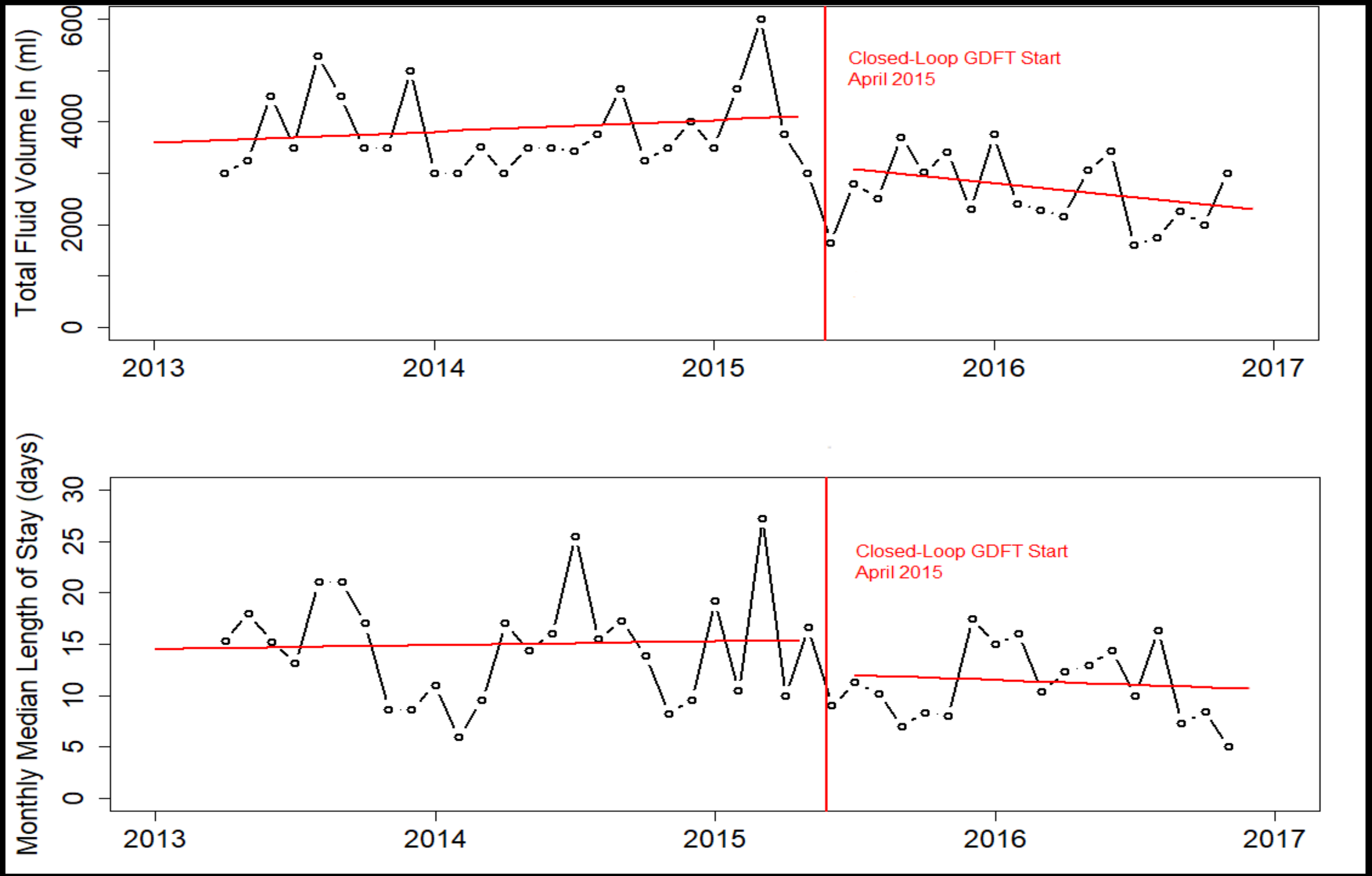
Objective : Assess the impact of our closed-loop system in patients undergoing major abdominal surgery at Erasme hospital without a GDFT programme

Primary outcome: Intraoperative net fluid balance

Secondary outcomes: Composite of major & minor complications and LOS

Joosten et al, EJA 2018

Time Series Analysis



4) Vasopressor administration

Current Practice

Blood pressure variability in surgical and intensive care patients: Is there a potential for closed-loop vasopressor administration?

Joseph Rinehart [a], Michael Ma [a], Michael David Calderon [a], Aurelie Bardaji [b], Reda Hafiane [b], Philippe Van der Linden [c], Alexandre Joosten [b,d,*]

- > 800 critically ill patients in the ICU
- > 2,500 high-risk surgical patients (major surgery)
- under continuous norepinephrine infusion (2014-2017)

Anaesth Crit Care Pain Med. 2019 Feb;38(1):69-71

OR and ICU Patients spent:

48.8% with a MAP [60- 80] mmHg
11.2% with MAP < 60 mmHg
40% with MAP > 80 mmHg

1) **Blood pressure management is suboptimal**

2) **There is room for improvement in the BP management of OR and ICU patients receiving vasopressor therapy**

3) **There may be a need for more accurate and timely titration**

7 research groups: Experimental research

Physician-Directed Versus Computerized Closed-Loop Control of Blood Pressure Using Phenylephrine in a Swine Model

Nicole Ribeiro Marques, MD,* William E. Whitehead, PhD,* Upendar R. Kallu, PhD,† Michael P. Kinsky, MD,* Joe S. Funston, MD,* Taoufik Wassar, PhD,† Muzna N. Khan, MS,* Mindy Milosch, MD,* Daniel Jupiter, PhD,‡ Karolos Grigoriadis, PhD,† and George C. Kramer, PhD*

USA

Uemura *et al. BMC Anesthesiology* (2017) 17:145
DOI 10.1186/s12871-017-0437-9

BMC Anesthesiology

TECHNICAL ADVANCE Open Access

Computer-controlled closed-loop drug infusion system for automated hemodynamic resuscitation in endotoxin-induced shock

Kazunori Uemura*, Toru Kawada, Can Zheng, Meihua Li and Masaru Sugimachi

JAPAN

Closed-loop double-vasopressor automated system to treat hypotension during spinal anaesthesia for caesarean section: a preliminary study

A. T. H. Sia, H. S. Tan, B. L. Sng

First published:28 September 2012 | https://doi.org/10.1111/anae.12000 | Cited by: 21

Singapore

Closed-Loop Feedback Computer-Controlled Phenylephrine for Maintenance of Blood Pressure During Spinal Anesthesia for Cesarean Delivery: A Randomized Trial Comparing Automated Boluses Versus Infusion

Warwick D. Ngan Kee, MD, FANZCA, FHKCA,* Yuk-Ho Tam, BSc, MPhil,* Kim S. Khaw, MD, FRCA, FHKCA,* Floria F. Ng, RN, BASc,* and Shara W. Y. Lee, PhD†

China

RESEARCH Open Access

Performance of closed-loop resuscitation of haemorrhagic shock with fluid alone or in combination with norepinephrine: an experimental study

Nicolas Libert[1,2], Guillaume Chenegros[3], Anatole Harrois[1,4], Nathalie Baudry[1], Gilles Cordurie[3], Ryad Benosman[3], Eric Vicaut[1,5] and Jacques Duranteau[1,4*]

France

Closed-loop regulation of arterial pressure after acute brain death

Kristian Soltesz[1] · Trygve Sjöberg[2] · Tomas Jansson[3] · Rolf Johansson[1] · Anders Robertsson[1] · Audrius Paskevicius[2] · Quiming Liao[2] · Guangqi Qin[2] · Stig Steen[2]

Sweden

Pre-clinical evaluation

In Silico studies

Journal of Clinical Monitoring and Computing

February 2018, Volume 32, Issue 1, pp 5–11 | Cite as

Feasibility of automated titration of vasopressor infusions using a novel closed-loop controller

Journal of Clinical Monitoring and Computing
https://doi.org/10.1007/s10877-018-0234-0

ORIGINAL RESEARCH

CrossMark

Closed-loop vasopressor control: in-silico study of robustness against pharmacodynamic variability

In Vivo study

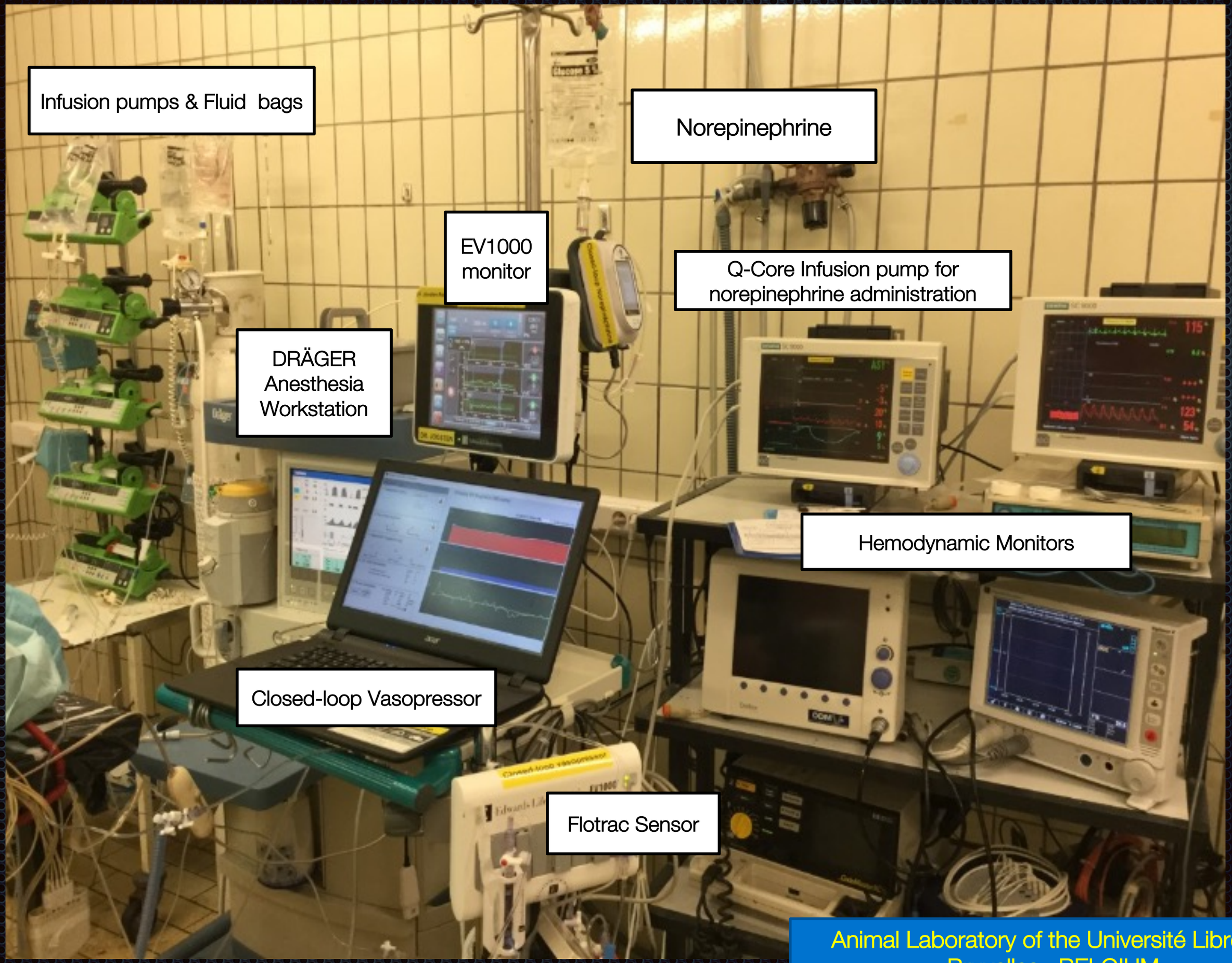
PERIOPERATIVE MEDICINE

ANESTHESIOLOGY

Automated Titration of Vasopressor Infusion Using a Closed-loop Controller

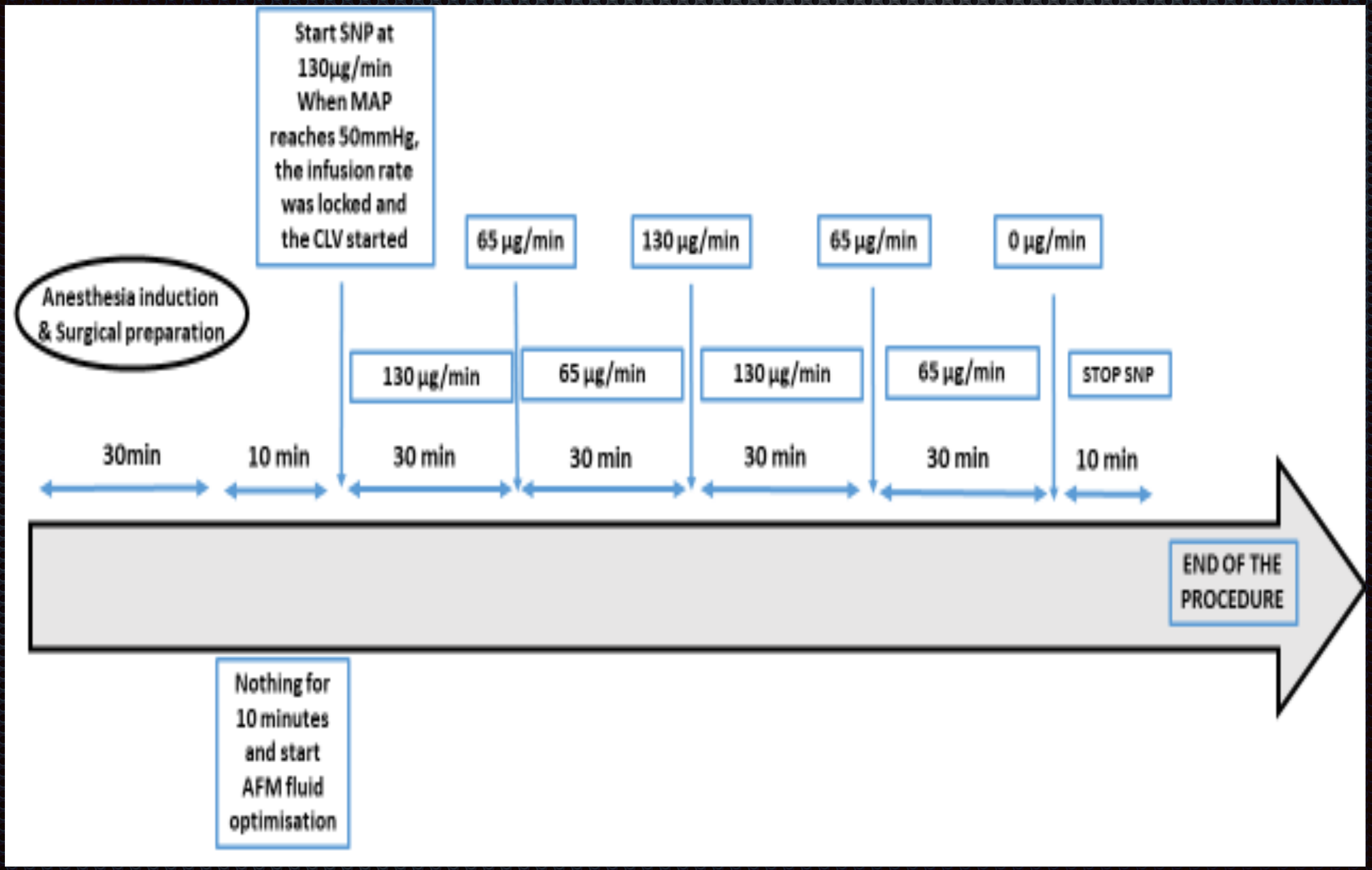
In Vivo Feasibility Study Using a Swine Model

Joosten et al, ANESTHESIOLOGY 2019

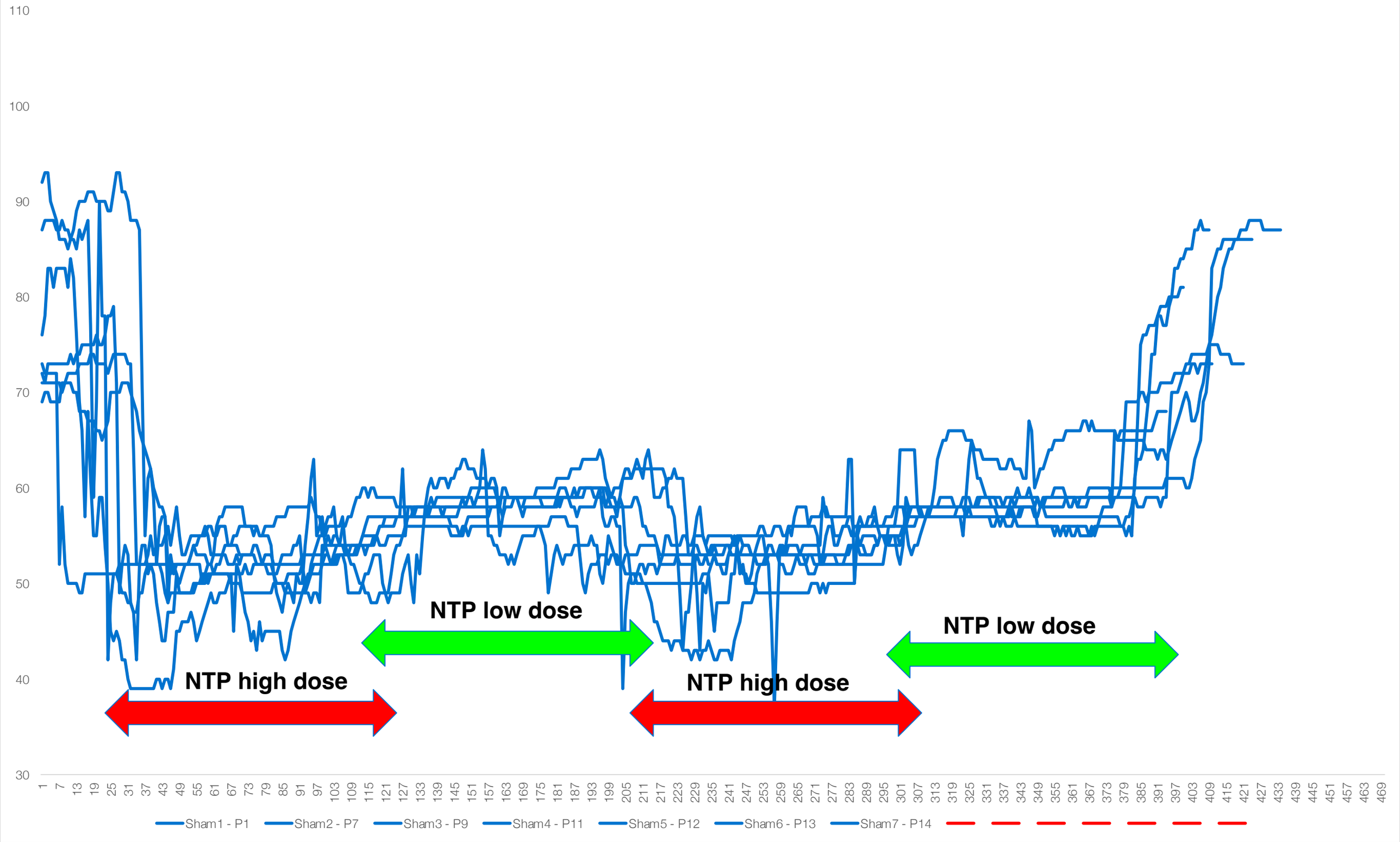


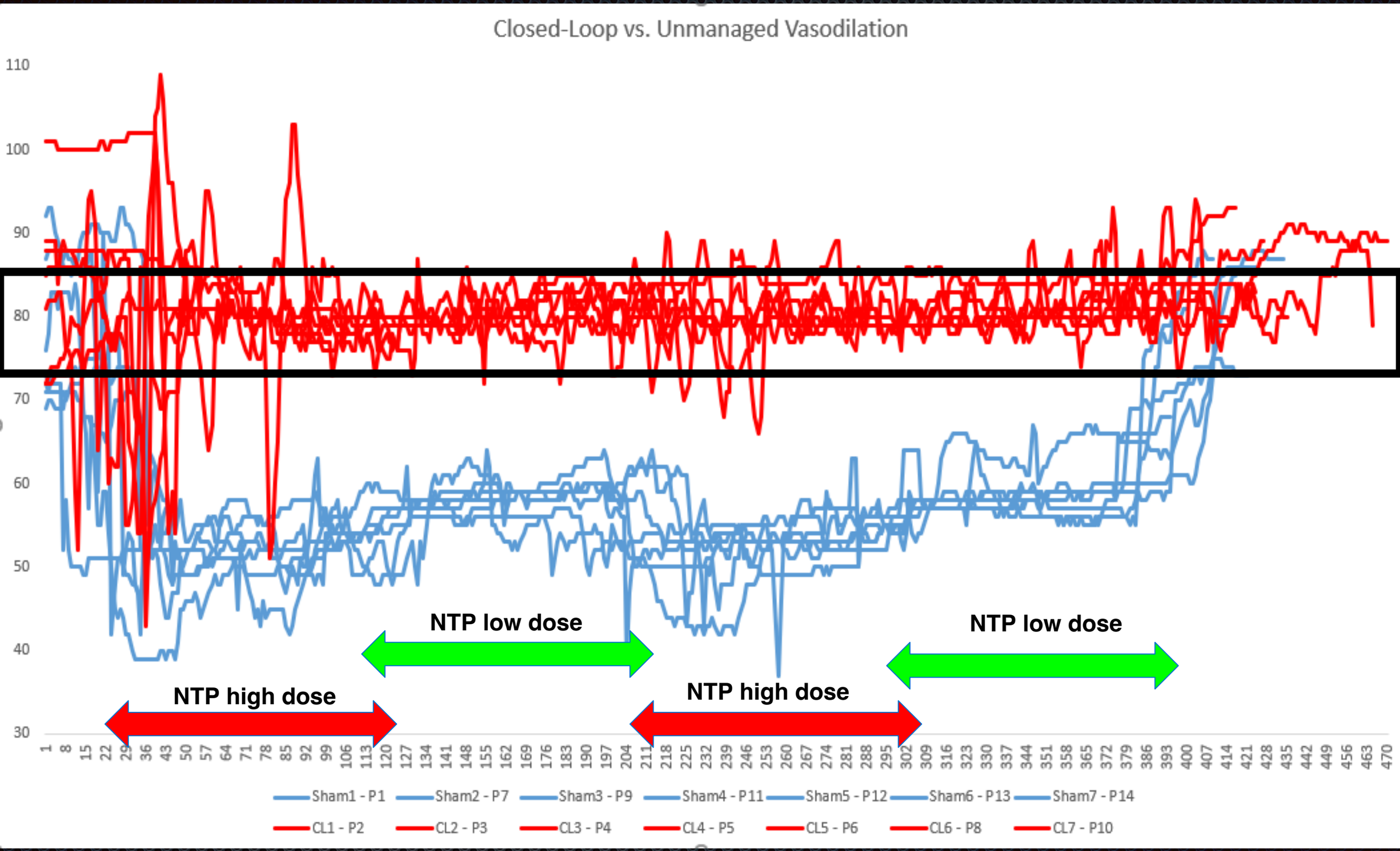
Animal Laboratory of the Université Libre de Bruxelles , BELGIUM

Experimental model of induced normovolemic hypotensive episodes (4 episodes of 30 min each < serum nitroprusside)



Closed-Loop vs. Unmanaged Vasodilation




Closed-Loop vs. Unmanaged Vasodilation
110
100
90
80
70
60
50
40
30
NTP low dose
NTP low dose
NTP high dose
NTP high dose
Sham1 - P1
Sham2 - P7
Sham3 - P9
Sham4 - P11
Sham5 - P12
Sham6 - P13
Sham7 - P14
CL1 - P2
CL2 - P3
CL3 - P4
CL4 - P5
CL5 - P6
CL6 - P8
CL7 - P10

Clinical studies in the Operating room?

KK Women's & Children's Hospital, Singapore

Chinese University of Hong Kong

Anaesthesia
Peri-operative medicine, critical care and pain
Association of Anaesthetists

Original Article | Free Access

Closed-loop double-vasopressor automated system to treat hypotension during spinal anaesthesia for caesarean section: a preliminary study

A. T. H. Sia, H. S. Tan, B. L. Sng

First published:28 September 2012 | https://doi.org/10.1111/anae.12000 | Cited by: 21

Anaesthesia
Peri-operative medicine, critical care and pain
Association of Anaesthetists

Original Article | Free Access

Closed-loop double-vasopressor automated system vs manual bolus vasopressor to treat hypotension during spinal anaesthesia for caesarean section: a randomised controlled trial

B. L. Sng, H. S. Tan, A. T. H. Sia

First published: 20 November 2013 | https://doi.org/10.1111/anae.12460 | Cited by: 29

J Clin Monit Comput (2017) 31:617–623
DOI 10.1007/s10877-016-9883-z

CrossMark

ORIGINAL RESEARCH

Performance of a closed-loop feedback computer-controlled infusion system for maintaining blood pressure during spinal anaesthesia for caesarean section: a randomized controlled comparison of norepinephrine versus phenylephrine

Warwick D. Ngan Kee[1] · Kim S. Khaw[1] · Yuk-Ho Tam[1] · Floria F. Ng[1] · Shara W. Lee[2]

Closed-Loop Feedback Computer-Controlled Phenylephrine for Maintenance of Blood Pressure During Spinal Anesthesia for Cesarean Delivery: A Randomized Trial Comparing Automated Boluses Versus Infusion

(Anesth Analg 2017;125:117–23)

Warwick D. Ngan Kee, MD, FANZCA, FHKCA,* Yuk-Ho Tam, BSc, MPhil,* Kim S. Khaw, MD, FRCA, FHKCA,* Floria F. Ng, RN, BASc,* and Shara W. Y. Lee, PhD†

1) Low-risk patients (C-Section-spinal Anesthesia)

2) Ephedrine and/or Phenylephrine

Hôpital Erasme | ULB

1) High-risk patients (under general anesthesia)

2) Norepinephrine infusion

BJA

British Journal of Anaesthesia, 123 (4): 430–438 (2019)

doi: 10.1016/j.bja.2019.04.064

Advance Access Publication Date: 27 June 2019

Cardiovascular

Feasibility of closed-loop titration of norepinephrine infusion in patients undergoing moderate- and high-risk surgery

20 patients

2.6 % **of case time under-target (Hypotension)**

2.4% **of case time over-target (Hypertension)**

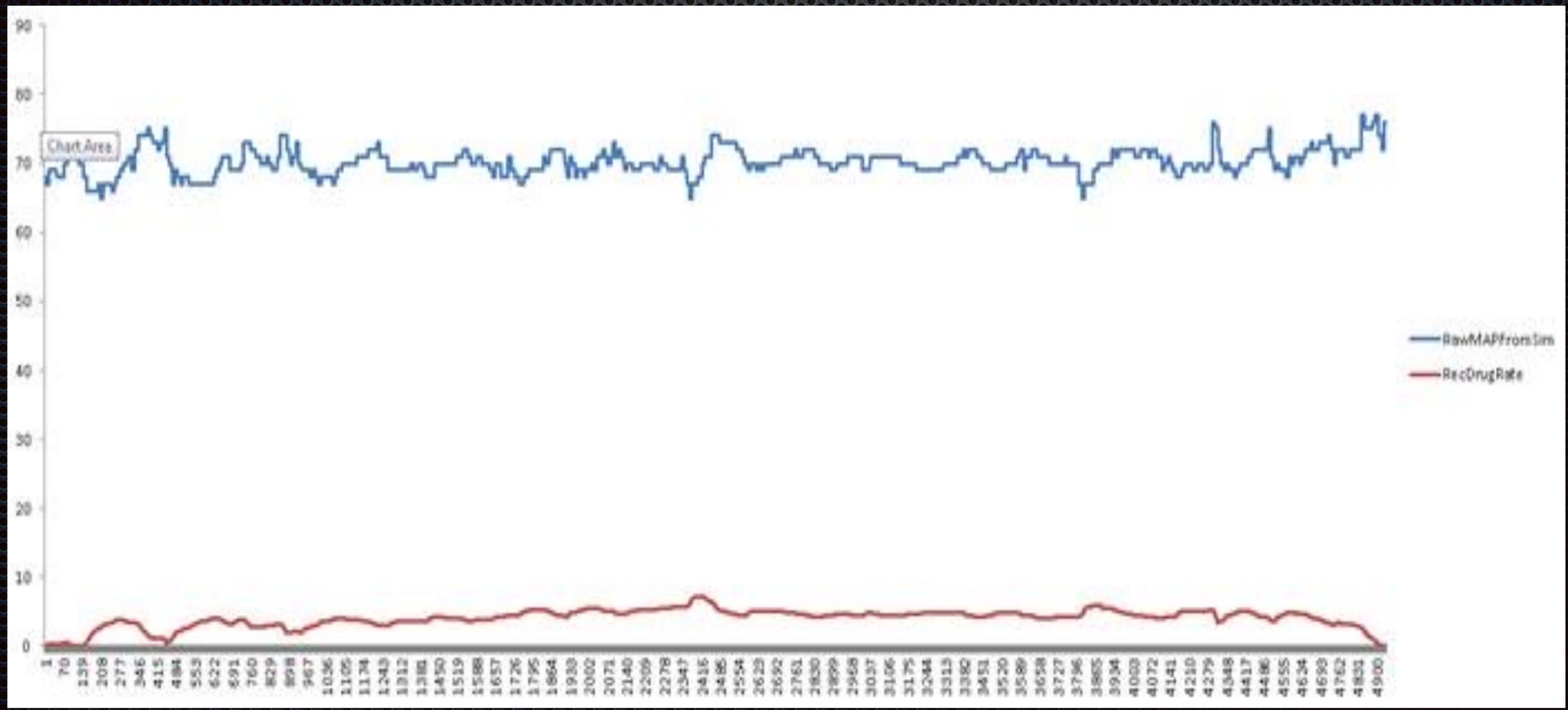
Joosten et al, BJA 2019

Aorto-Bifemoral Bypass Surgery

ERASME Hospital
Brussels BELGIUM

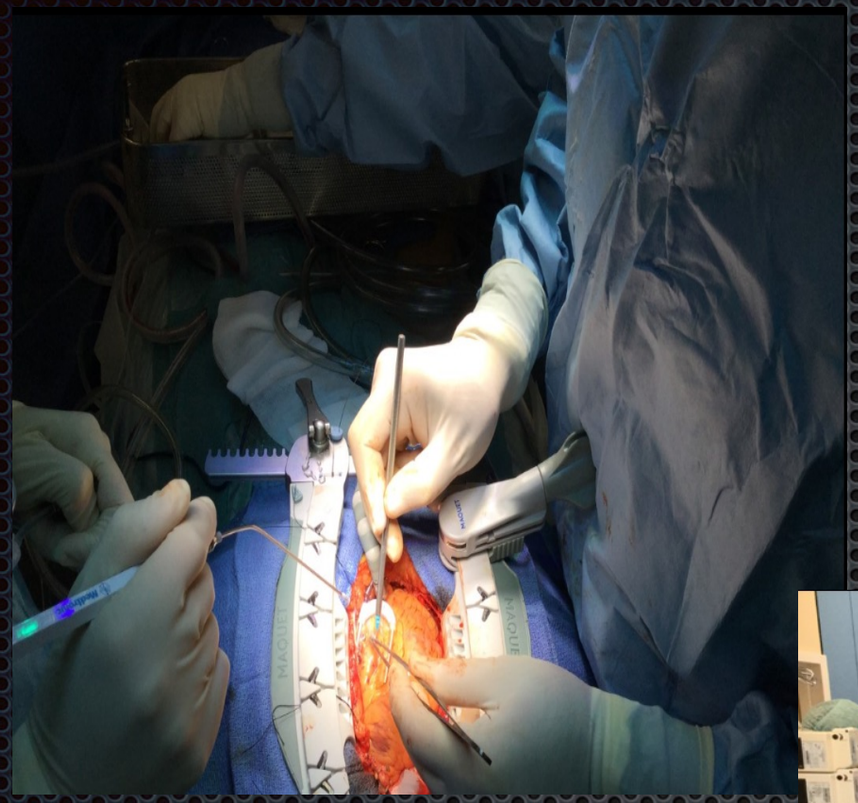
TARGET MAP at 70mmHg ± 5 mmHg

0% case time with a MAP < 65 mmHg



Closed-Loop Control of Vasopressor Administration in Patients Undergoing Cardiac Revascularization Surgery

OFF-PUMP



MIDCAB

ON-PUMP

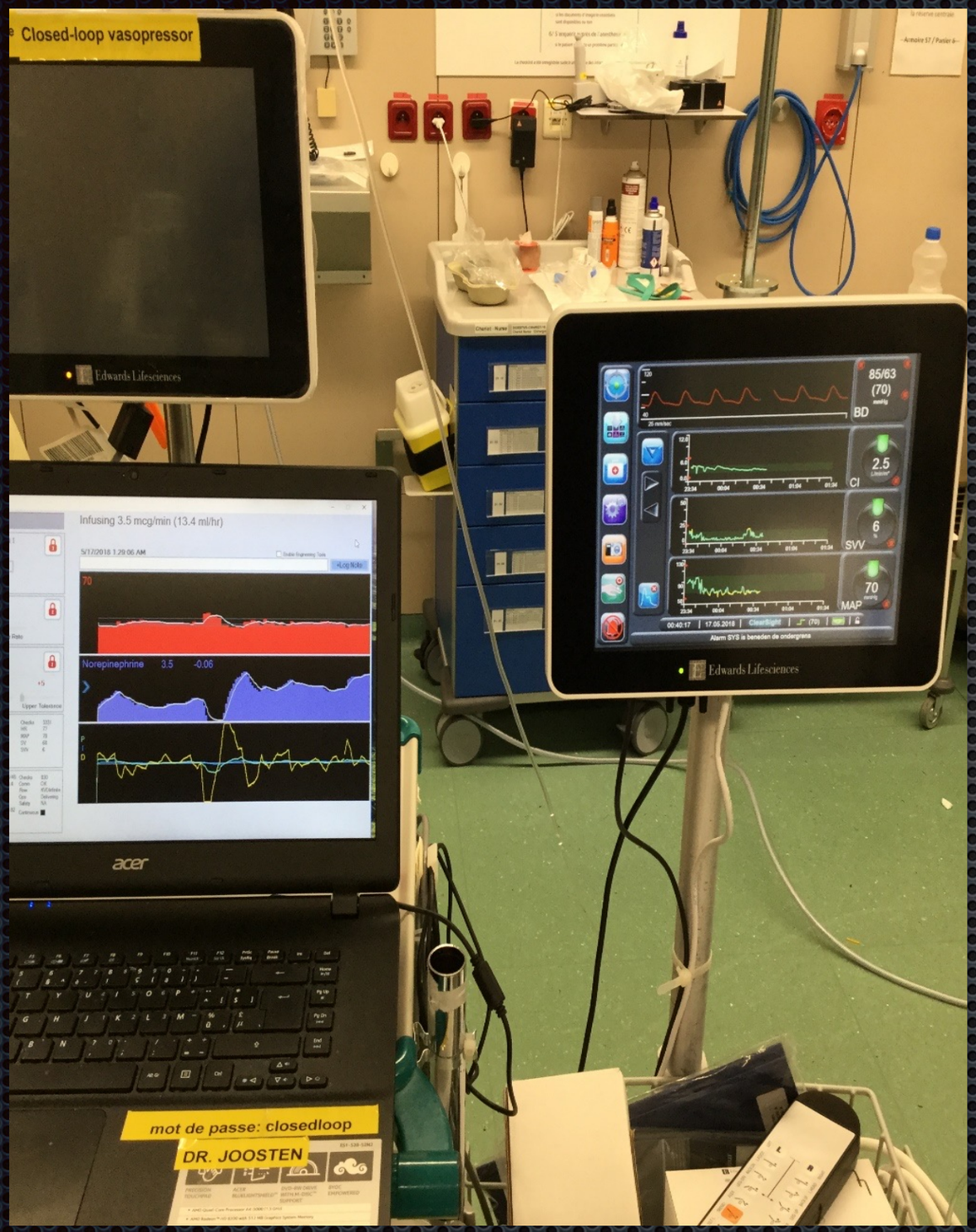
Joosten et al J Cardiothorac Vasc Anesth. 2020

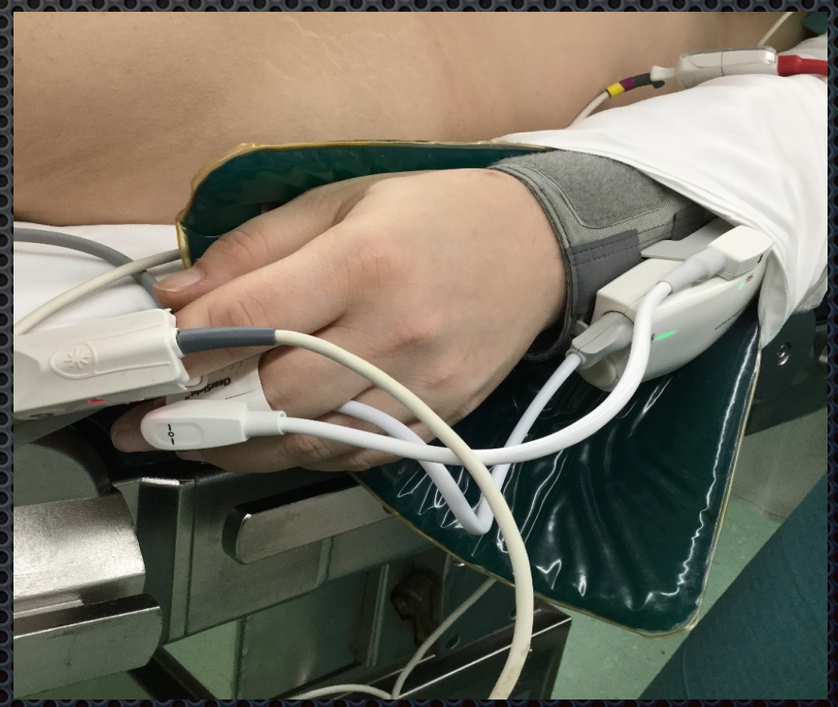

PHILIPS
Bras-02
Closed-loop vasopressor
Closed-loop vasopressor

ROBOTIC CARDIAC SURGERY

ON-PUMP CARDIAC SURGERY

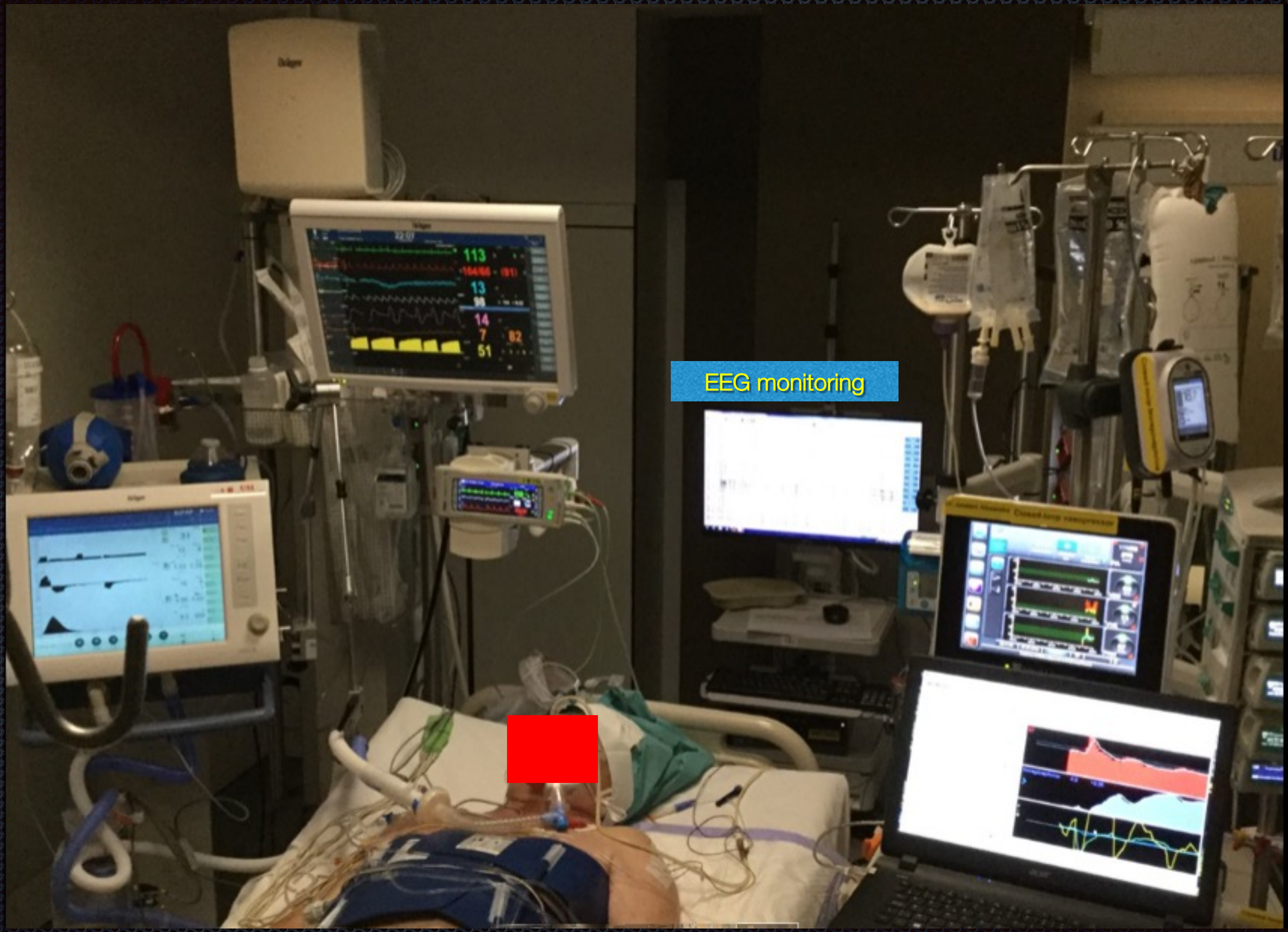
Feasibility of computer-assisted vasopressor infusion using continuous non-invasive blood pressure monitoring in high-risk patients undergoing renal transplant surgery



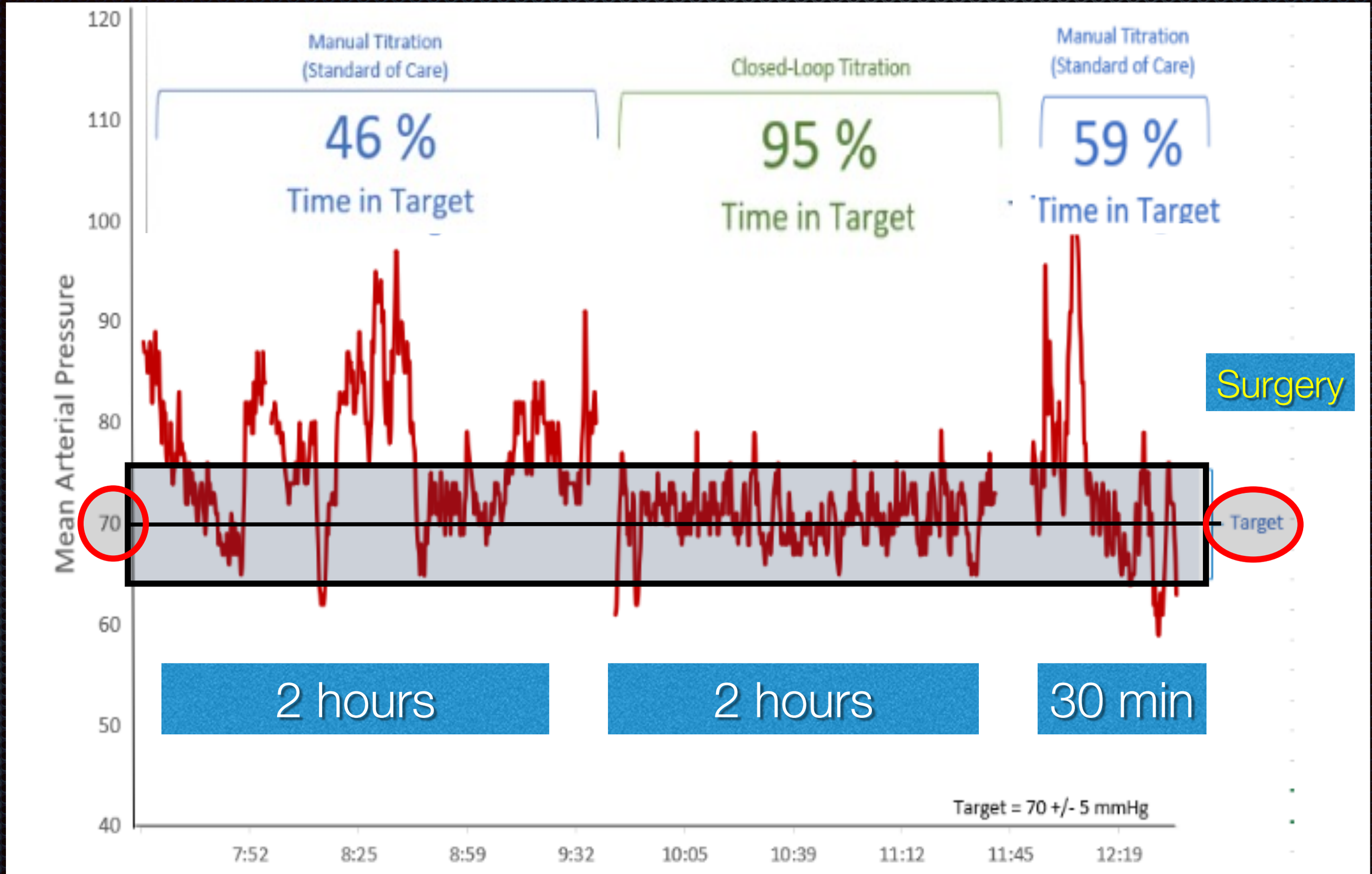


Joosten et al **Anaesth Crit Care Pain Med. 2020**

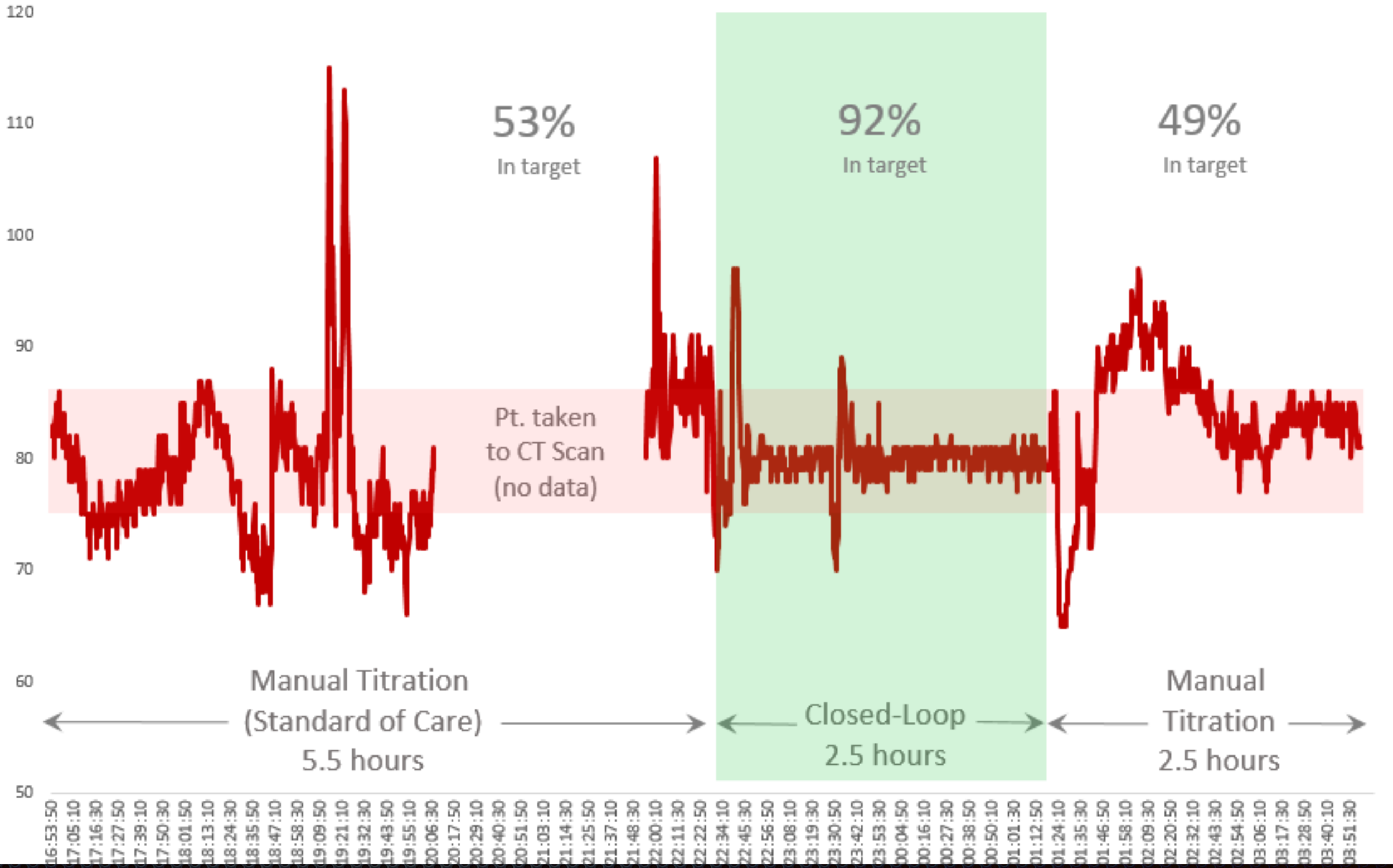
Neuro embolization of cerebral aneurysm


EEG monitoring

Mean Arterial Pressure - Manual *versus* Closed-Loop Management



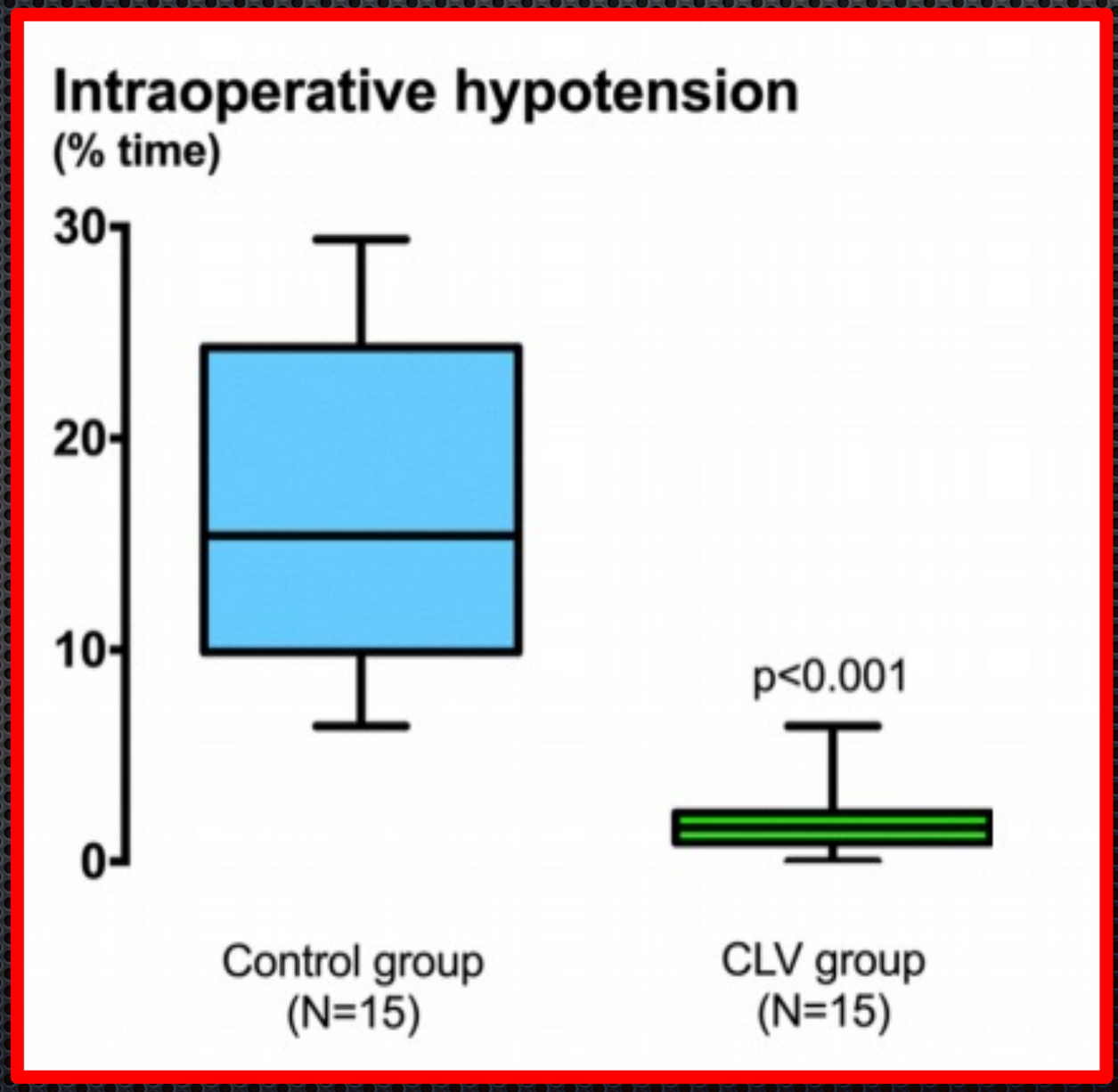
Mean Arterial Pressure in Neurotrauma Over First 11 Hours



CLINICAL INVESTIGATION

Automated closed-loop *versus* manually controlled norepinephrine infusion in patients undergoing intermediate- to high-risk abdominal surgery: a randomised controlled trial

BJA



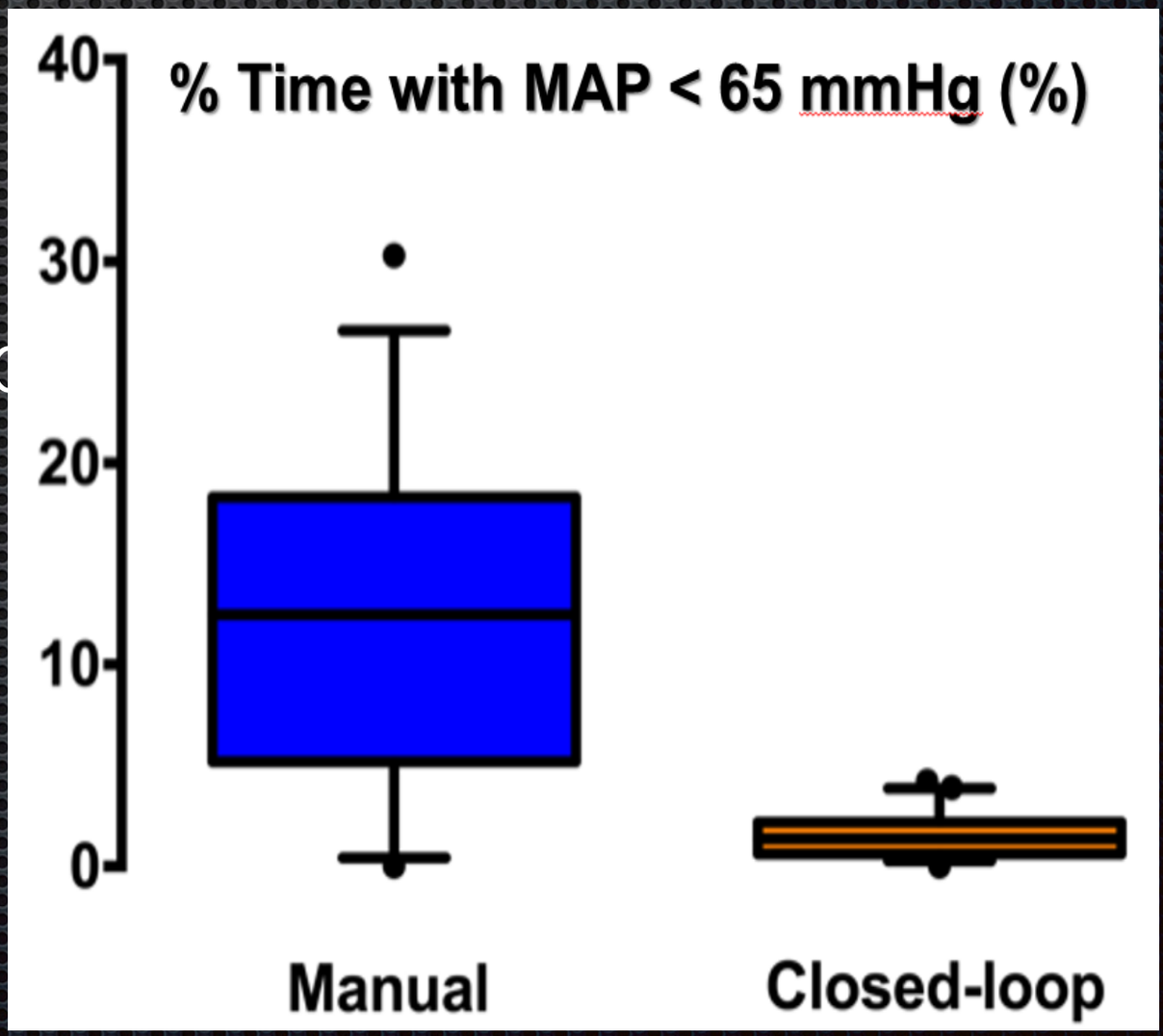
Joosten et al, BJA 2020

ORIGINAL CLINICAL RESEARCH REPORT

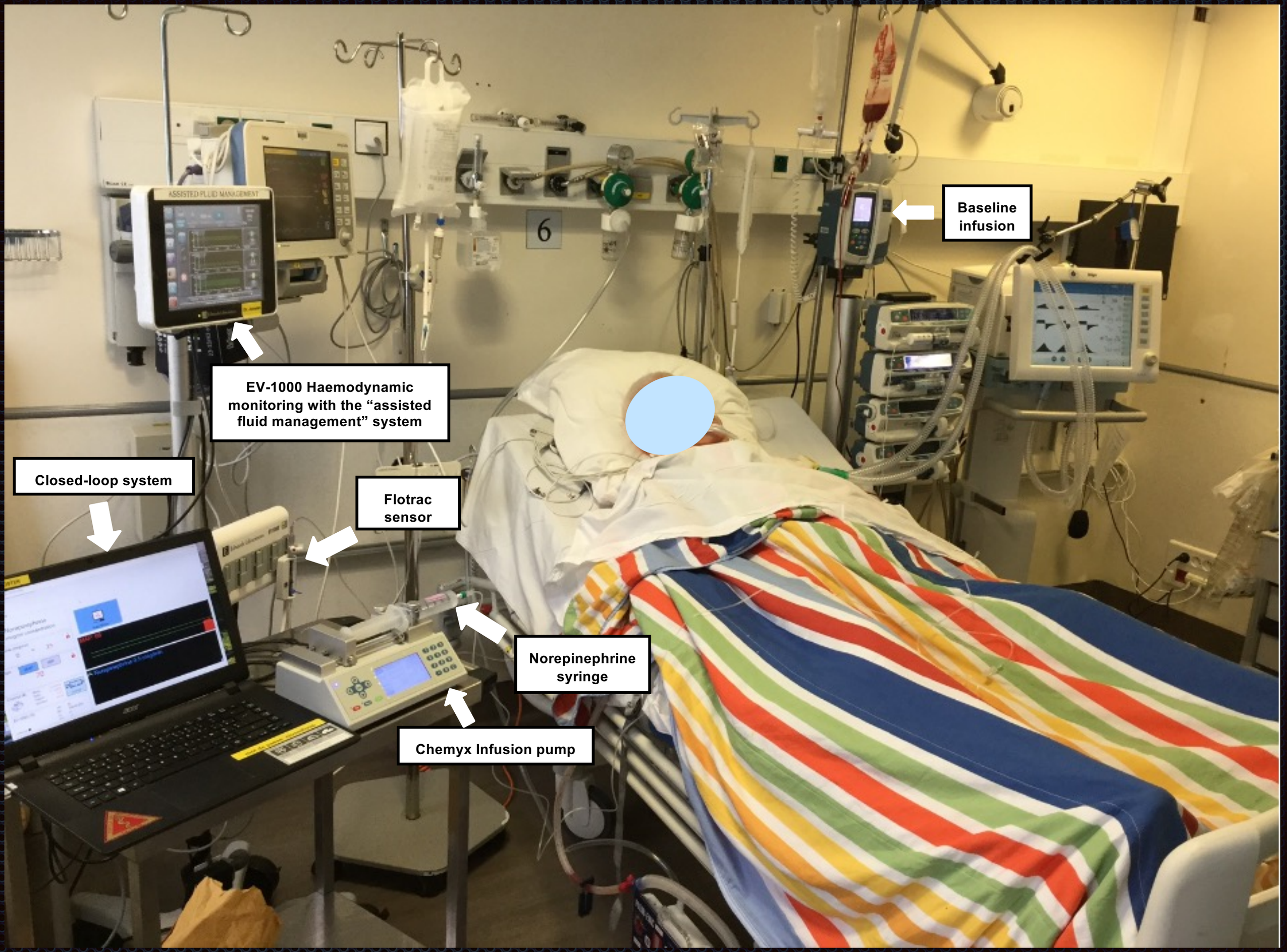
Control of Postoperative Hypotension Using a Closed-Loop System for Norepinephrine Infusion in Patients After Cardiac Surgery: A Randomized Trial

40 patients: RCT (manual vs automated adjustments of noradrenaline)

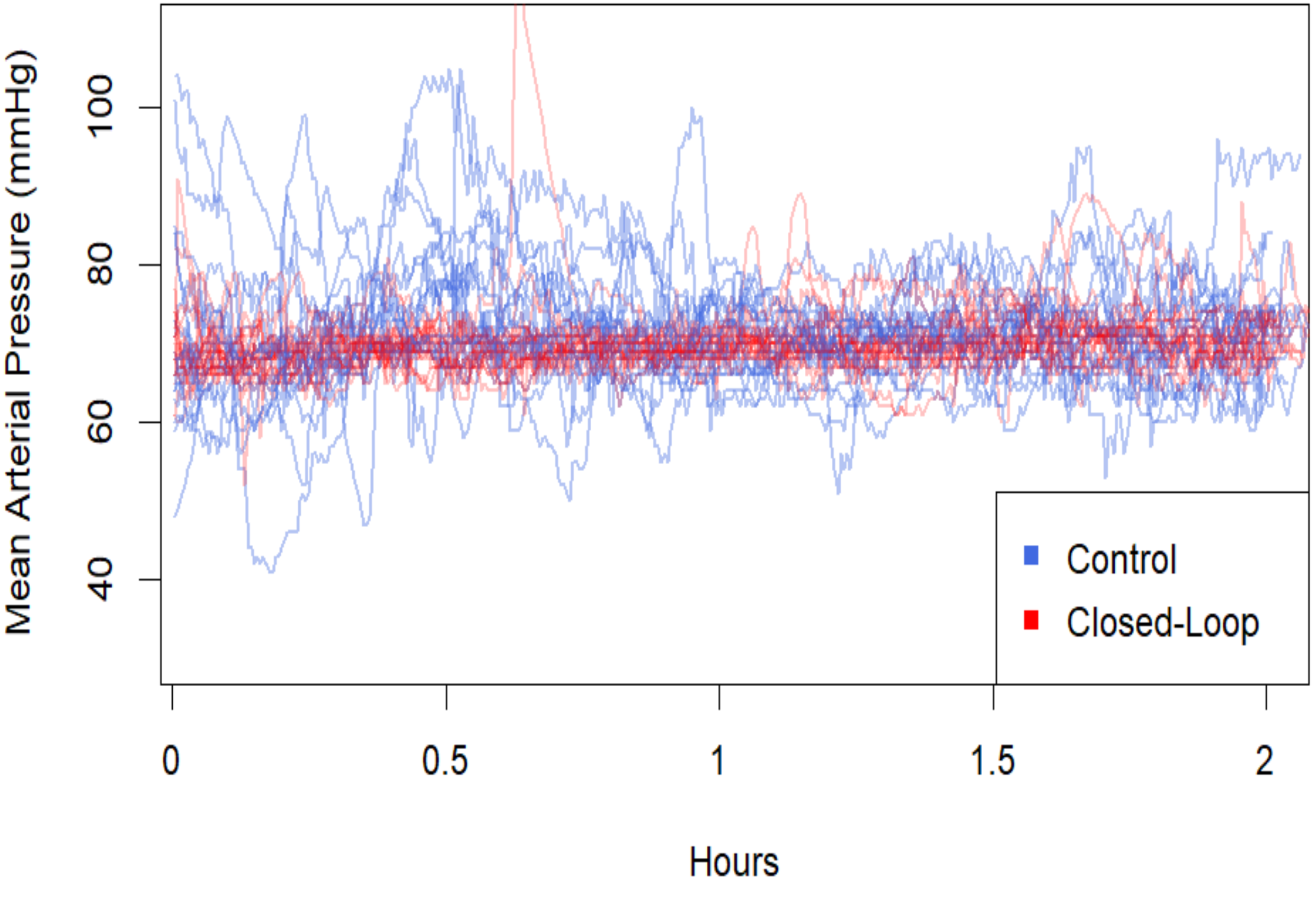
Primary objective: % postop stud
period with a MAP < 65 mmHg



Desebbe et al, A&A 2022

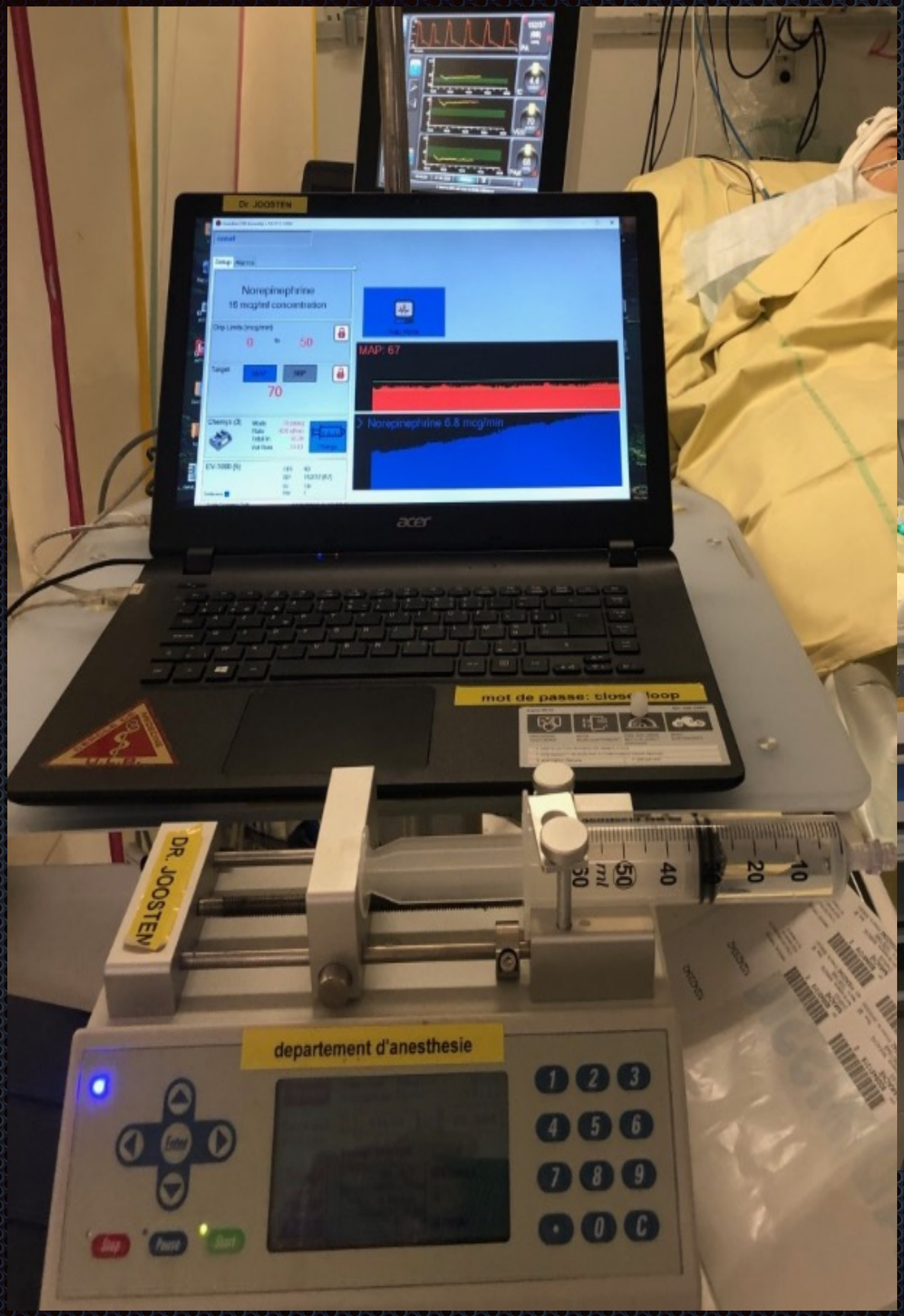

ASSISTED FLUID MANAGEMENT
6
EV-1000 Haemodynamic monitoring with the “assisted fluid management” system
Baseline infusion
Closed-loop system
Flotrac sensor
Norepinephrine syringe
Chemyx Infusion pump

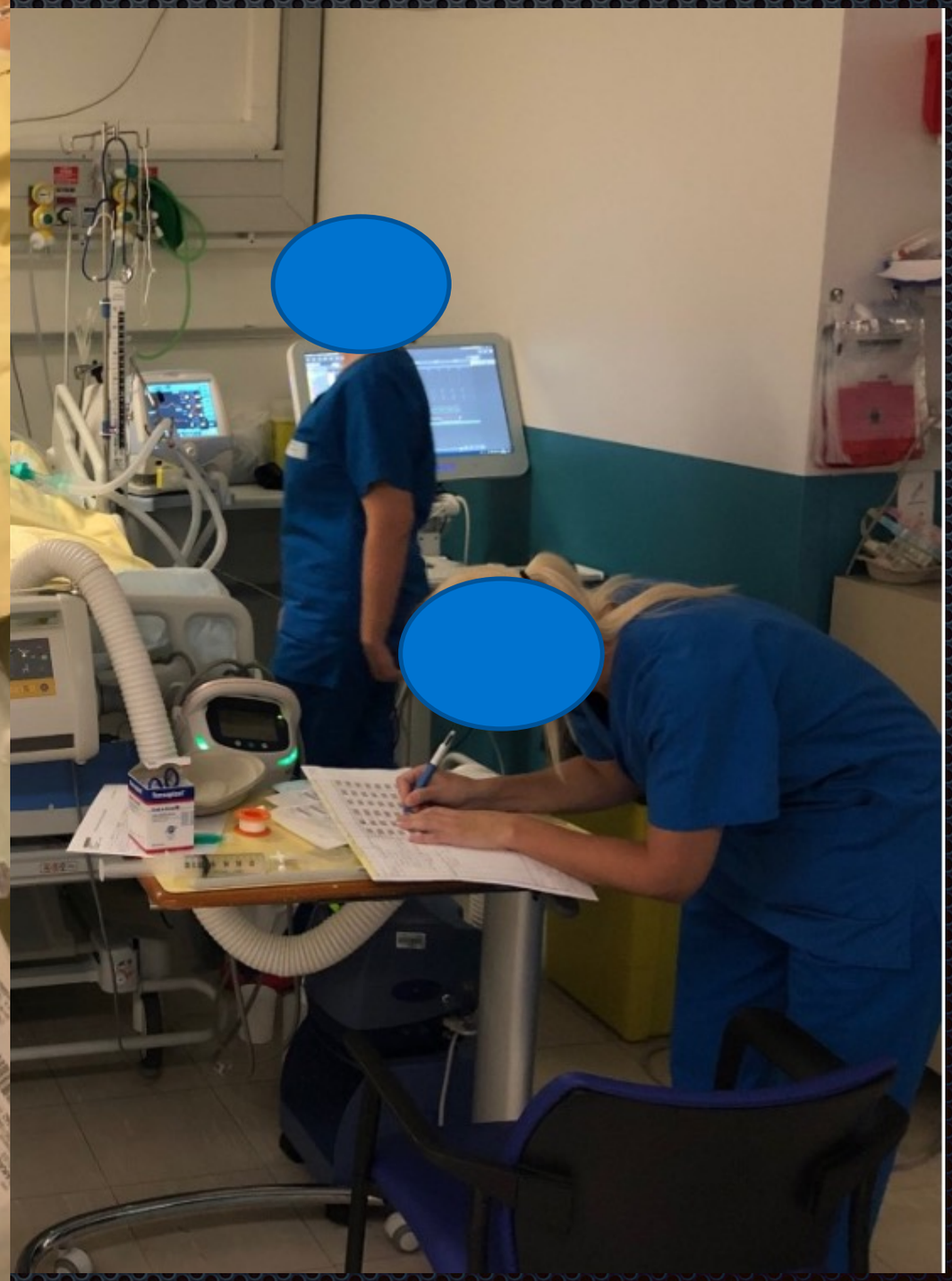
Mean Arterial Pressure in All Cases

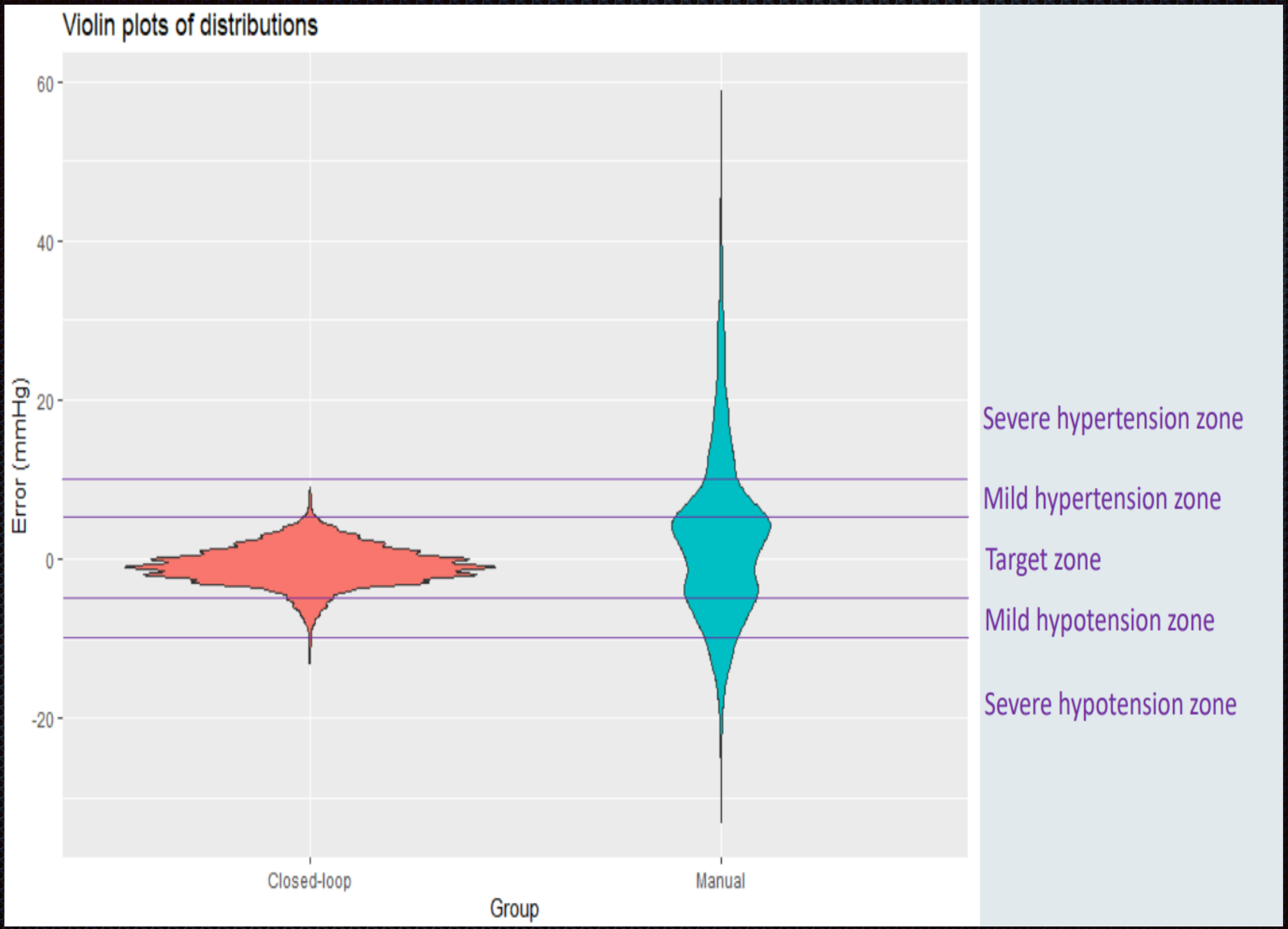


« COMAT » study

Control MAP Brain Injury Patients


Dr JOOSTEN
Norepinephrine
16 mcg/ml concentration
0
to
50
70
MAP: 67
Norepinephrine 6.8 mcg/min
acer
mot de passe: close loop
DR. JOOSTEN
departement d'anesthesie
1 2 3
4 5 6
7 8 9
. 0 C




Violin plots of distributions
60
40
20
0
-20
Error (mmHg)
Closed-loop
Manual
Group
Severe hypertension zone
Mild hypertension zone
Target zone
Mild hypotension zone
Severe hypotension zone

2018

Rodent model of haemorrhagic shock

Libert *et al. Ann. Intensive Care (2018) 8:89*
https://doi.org/10.1186/s13613-018-0436-0

Annals of Intensive Care

RESEARCH Open Access

Performance of closed-loop resuscitation of haemorrhagic shock with fluid alone or in combination with norepinephrine: an experimental study

Nicolas Libert[1,2], Guillaume Chenegros[3], Anatole Harrois[1,4], Nathalie Baudry[1], Gilles Cordurie[3], Ryad Benosman[3], Eric Vicaut[1,5] and Jacques Duranteau[1,4*]

2020

Pig model of haemorrhagic shock

Journal of Clinical Monitoring and Computing
https://doi.org/10.1007/s10877-020-00542-7

ORIGINAL RESEARCH

Performance of closed-loop resuscitation in a pig model of haemorrhagic shock with fluid alone or in combination with norepinephrine, a pilot study

Nicolas Libert[1,2] · Guillaume Chenegros[3] · Anatole Harrois[1,4] · Nathalie Baudry[1] · Benoit Decante[5] · Gilles Cordurie[3] · Ryad Benosman[3] · Olaf Mercier[6,7] · Eric Vicaut[1,8] · Jacques Duranteau[1,4]

ANESTHESIOLOGY

Computer-assisted Individualized Hemodynamic Management Reduces Intraoperative Hypotension in Intermediate- and High-risk Surgery: A Randomized Controlled Trial

ANESTHESIOLOGY 2021

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Protocole hémodynamique individualisé péri-opératoire pour les chirurgies/patients à risque cardiovasculaire

Hôpitaux universitaires Paris-Sud

UNIVERSITÉ PARIS SUD

- Echocardiographie pré-opératoire
- PAM de référence du patient (PAM en consultation d'Anesthésie ou PAM prise en salle la veille de l'intervention)
- Perfusion de base (NaCl 0,9% ou Ringer Lactate) : 2 ml/kg/h pour laparoscopie et 4 ml/kg/h pour laparotomie (Pompe volumétrique)

En péri-induction, avant mise en place d'un moniteur hémodynamique

- Initiation perfusion continue de noradrenaline (100 µg/mL) (100 µg/h à 200 µg/h)
- But ± 10% PAM de référence (sans jamais <PAM 65 mmHg)
- Possibilité d'un remplissage vasculaire maximum de 500 mL cristalloïdes

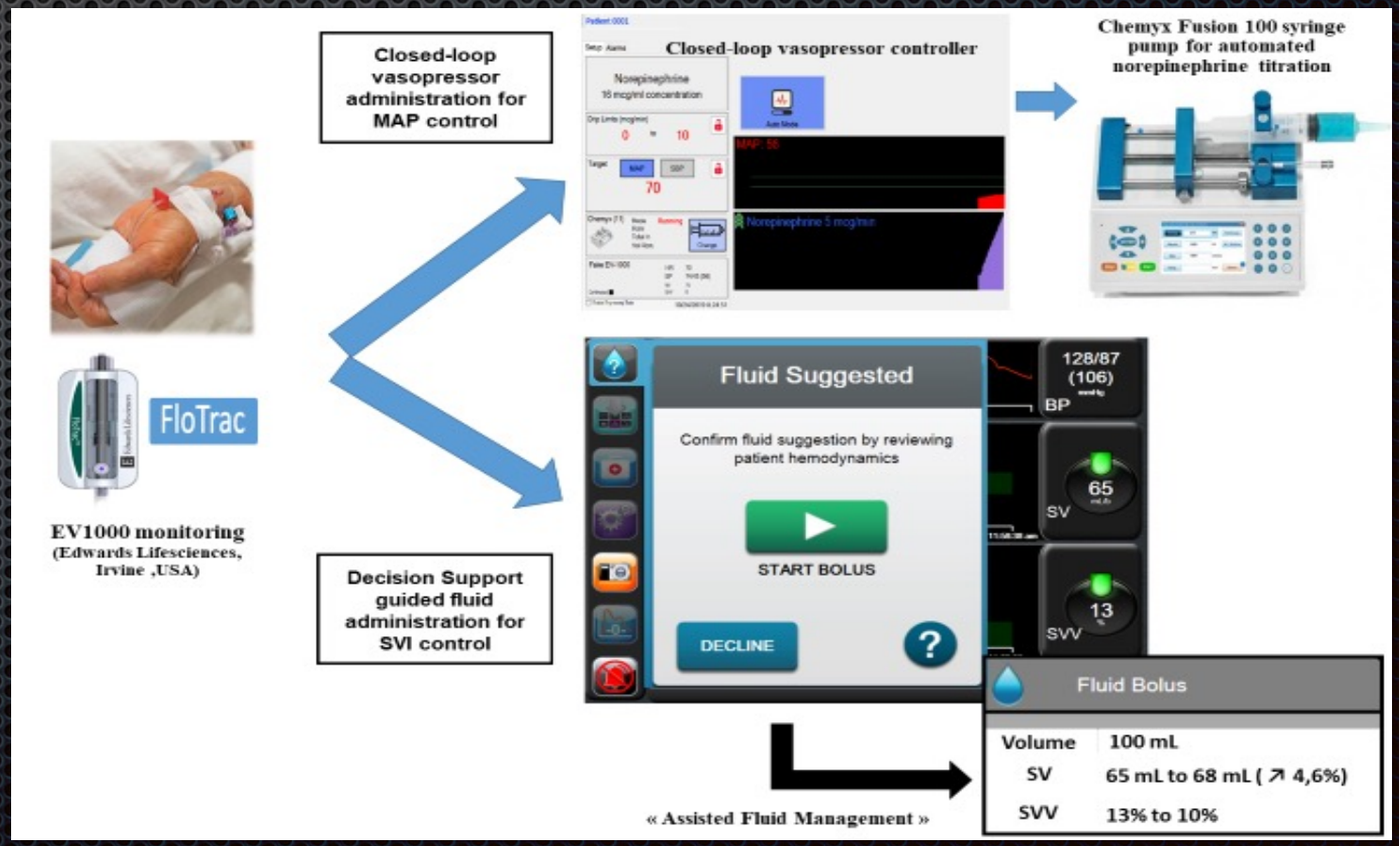
mise en place d'un moniteur hémodynamique après stabilisation et installation du patient

- Evaluation du Volume d'Ejection Systolique Indexé (VESi) (normales 40-60 mL/m²)
- Optimisation du VESi : épreuve de remplissage (ER) (100 mL en 1 min). Si répondeur (augmentation ≥10% du VESi) compléter à 250 mL. Si augmentation du VESi ≥10% après les 250 mL, refaire 250 mL (Donc au maximum de 500 mL)
- VESi obtenu après optimisation = VESi de référence

Au cours de la chirurgie

- Buts : ± 10% VESi référence et ± 10% PAM de référence
- Si baisse du VESi >10% par rapport au VESi référence : épreuve(s) de remplissage (100 mL en 1 min) pour ± 10% VESi référence
- Titration de la noradrénaline: but = ± 10% PAM de référence
- Si baisse simultanée de la PAM et du VESi : augmentation de la noradrénaline pour ± 10% PAM de référence et épreuve(s) de remplissage (100 mL en 1 min) pour ± 10% VESi référence
- Si malgré ER et noradrénaline, VESi < 40 mL/m2 (ou si Index Cardiaque < 2,5 ml/kg/m²) : discuter agent inotrope (Dobutamine - Adrénaline)
- Si hemoglobine ≤7 g/dL transfusion d'une unité de culots globulaires
- Surveillance : lactate (si catheter artériel) et diurèse /h

VS



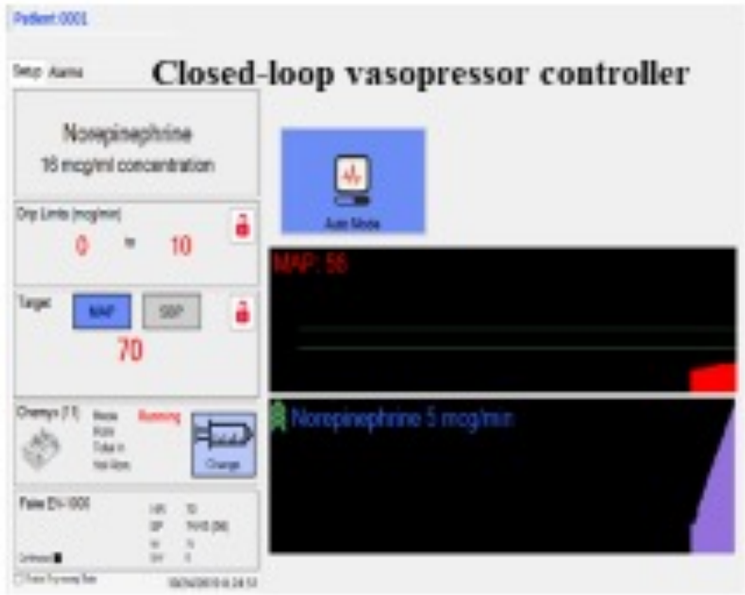
Joosten et al, ANESTHESIOLOGY 2021

FIGURE 1

Computer-assisted Goal Directed Therapy protocol

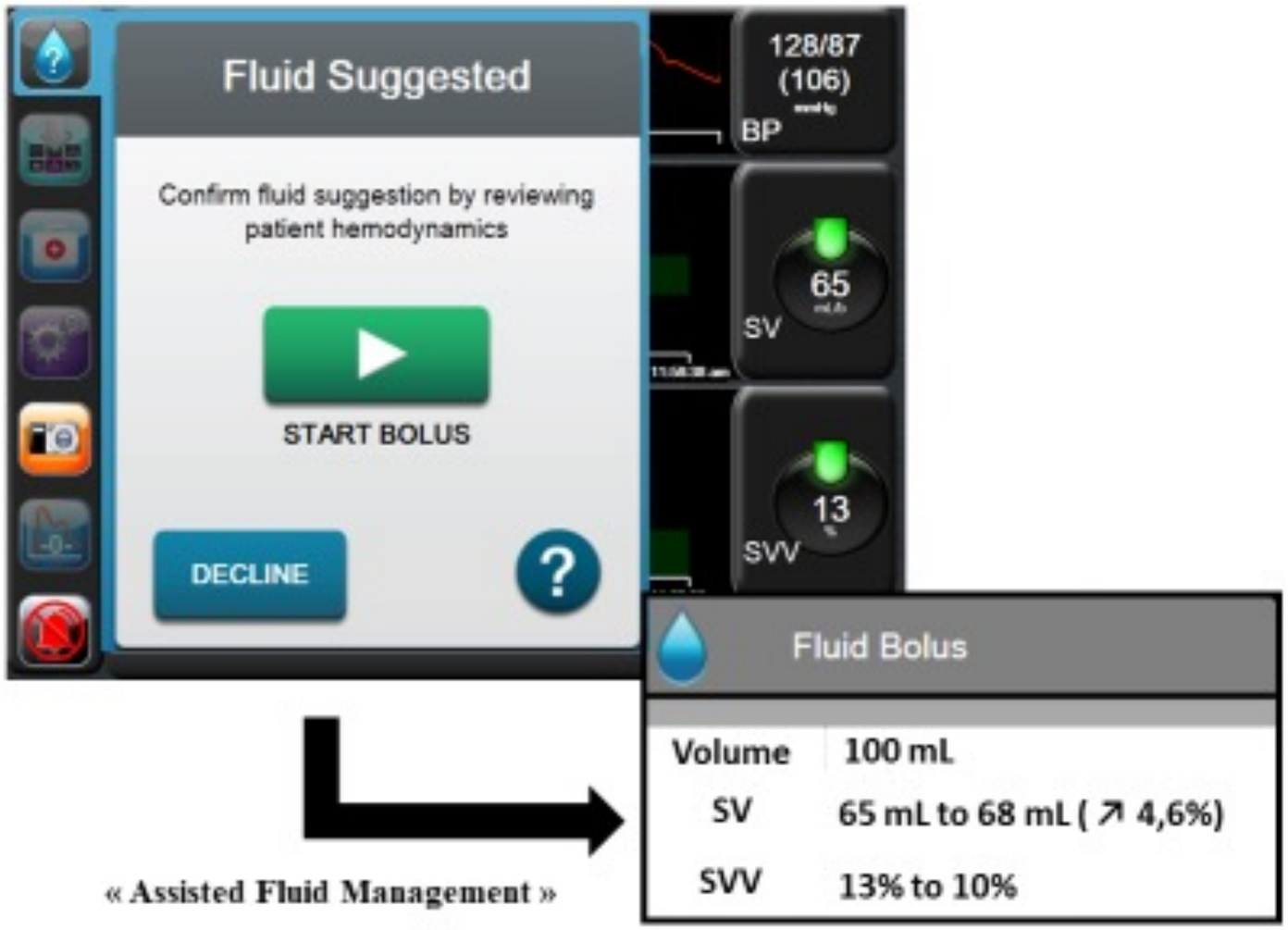
EV1000 monitoring
(Edwards Lifesciences, Irvine ,USA)

Closed-loop vasopressor administration for MAP control

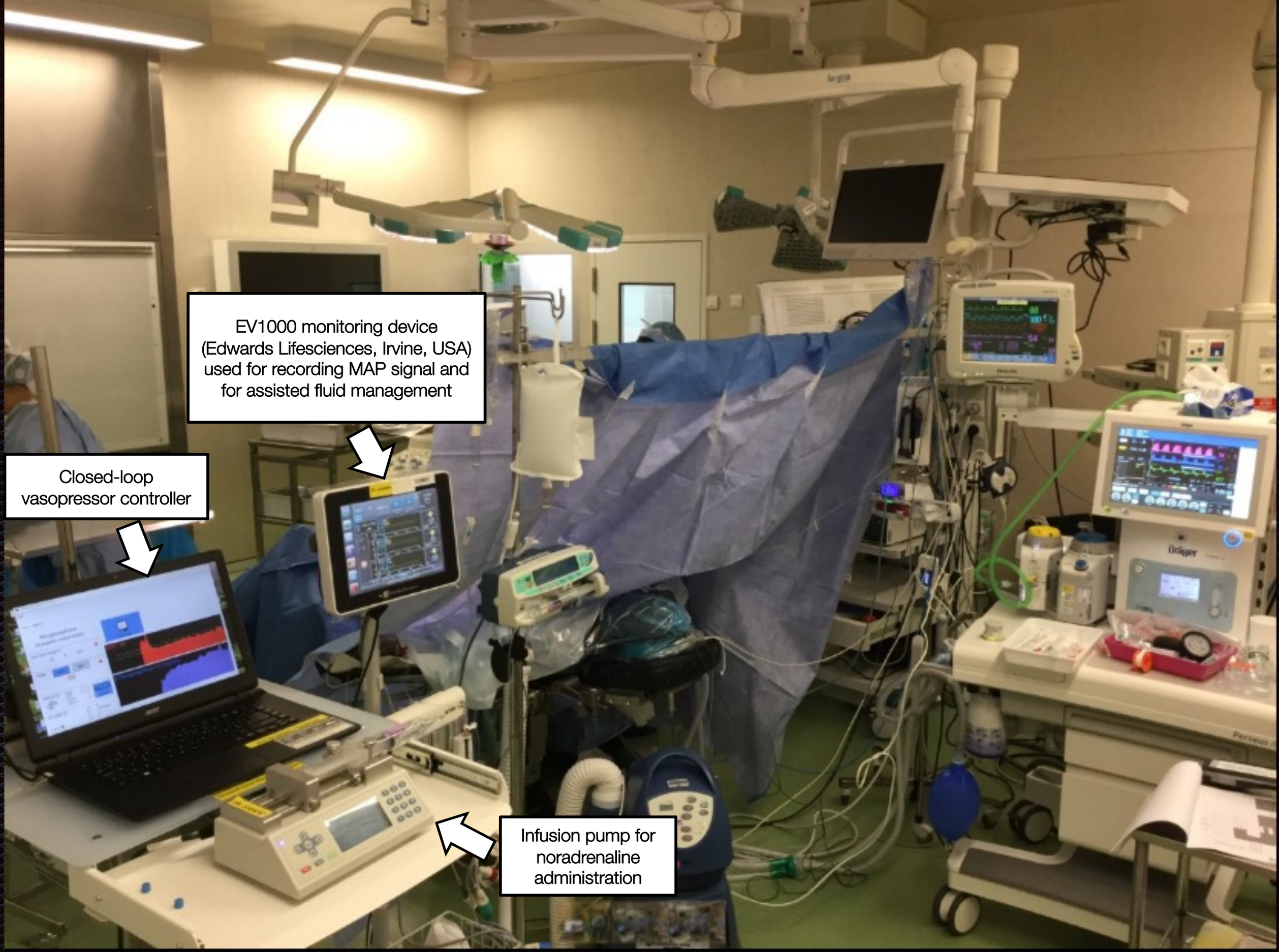


Chemyx Fusion 100 syringe pump for automated norepinephrine titration

Decision Support guided fluid administration for SVI control



« Assisted Fluid Management »

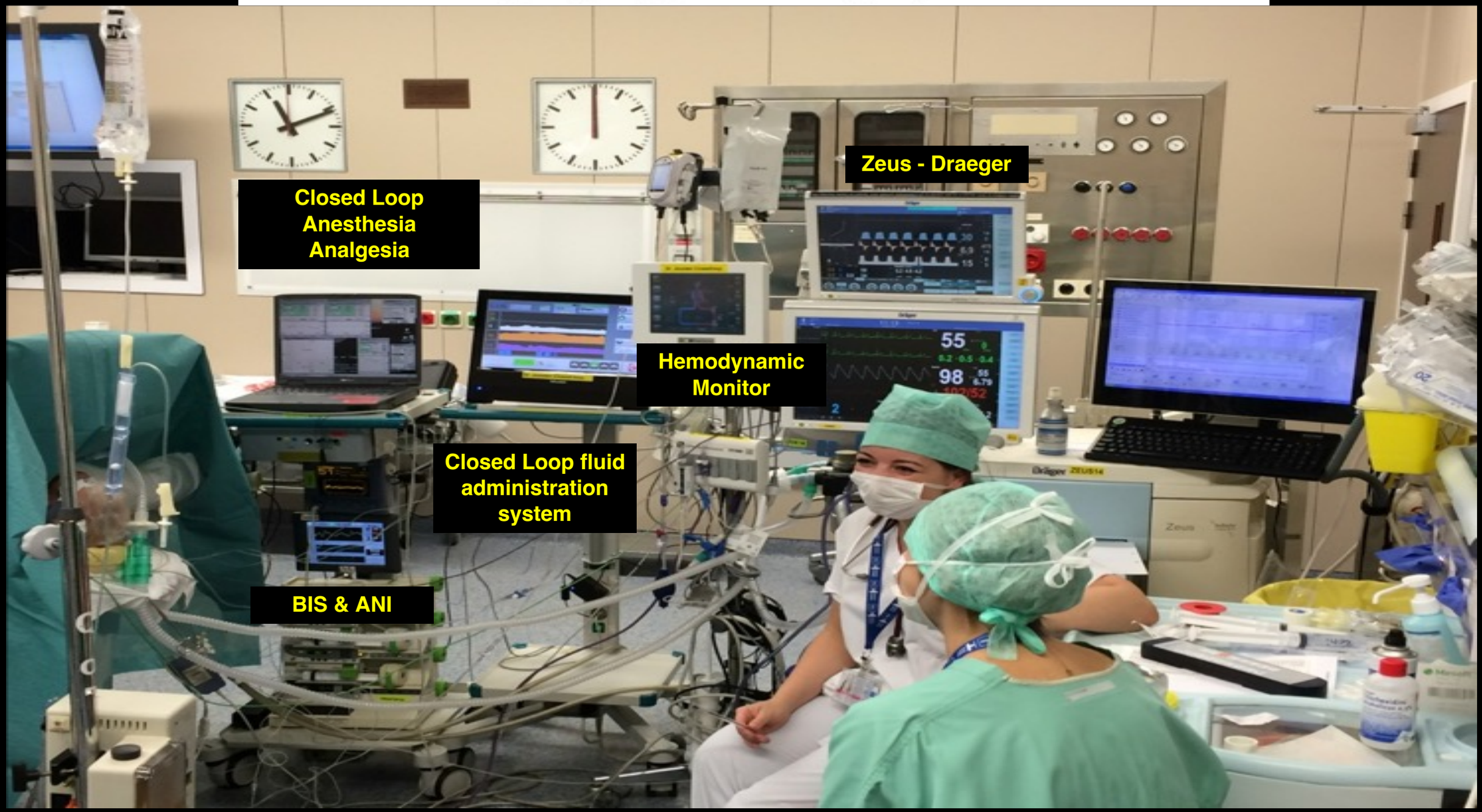

EV1000 monitoring device (Edwards Lifesciences, Irvine, USA) used for recording MAP signal and for assisted fluid management
Closed-loop vasopressor controller
Infusion pump for noradrenaline administration

Heatmap of Mean Arterial Pressure Error & Stroke Volume Index in All Cases by Group

A&A 2016 Dec 15;7(12):260-265

CASE REPORT

Fully Automated Anesthesia and Fluid Management Using Multiple Physiologic Closed-Loop Systems in a Patient Undergoing High-Risk Surgery



Joosten et al, A&A 2016

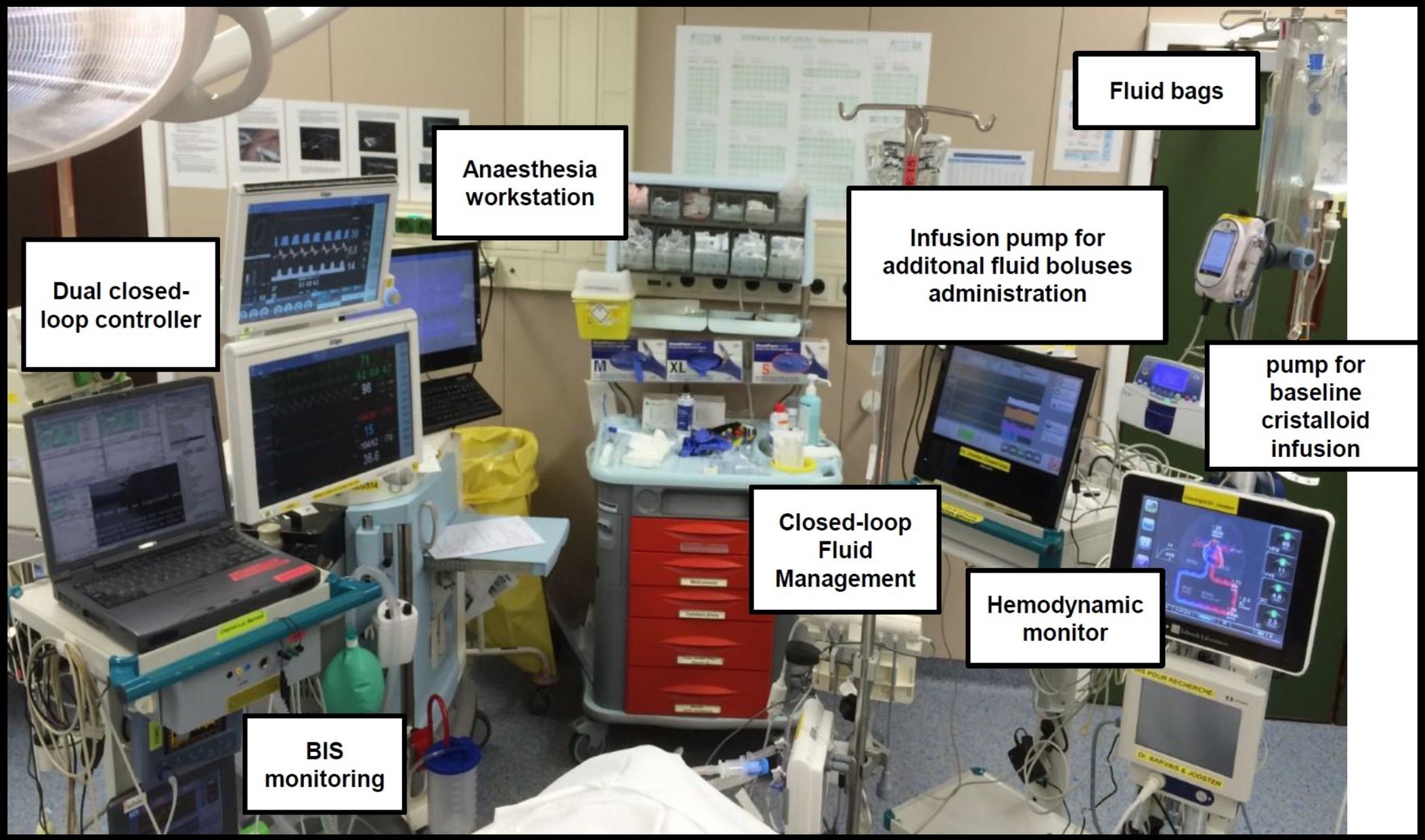
Technology, Computing, and Simulation

Section Editor: **Maxime Cannesson**

BRIEF REPORT

Anesth Analg 2019;128:e88–92

Feasibility of Fully Automated Hypnosis, Analgesia, and Fluid Management Using 2 Independent Closed-Loop Systems During Major Vascular Surgery: A Pilot Study



Joosten et al, A&A 2019

Impact on patient outcome

PERIOPERATIVE MEDICINE

ANESTHESIOLOGY

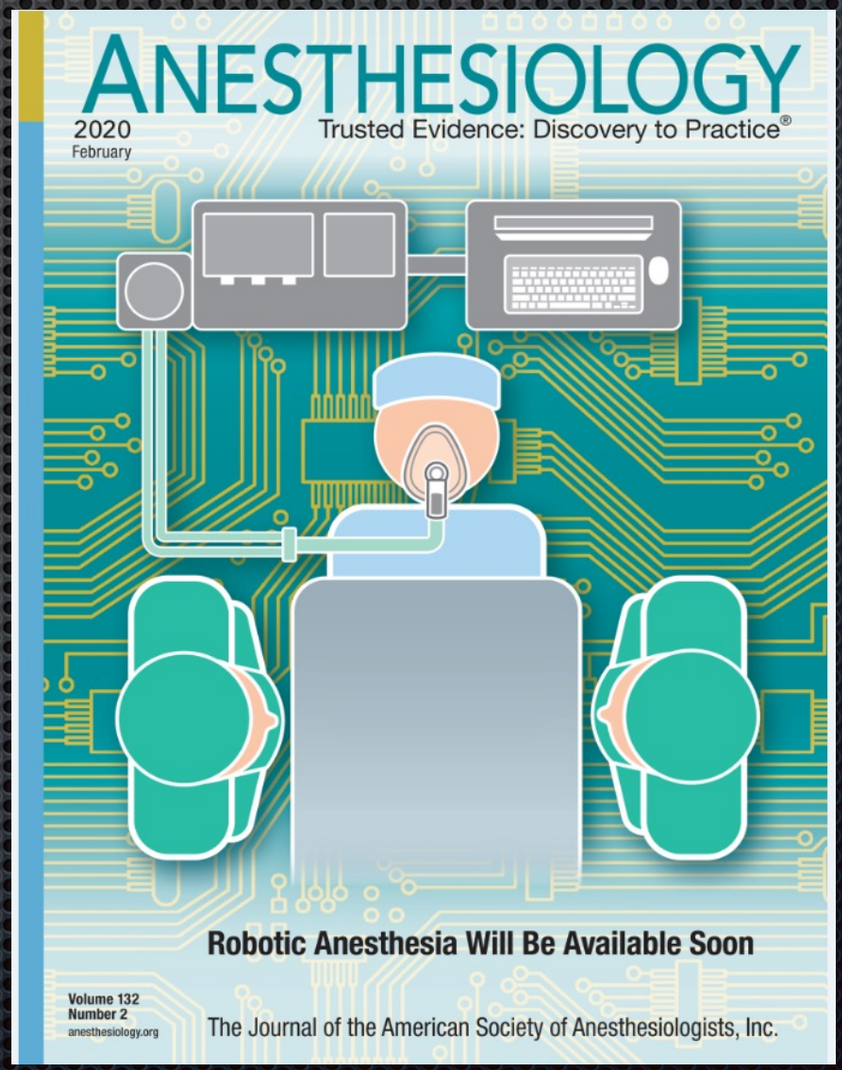
Anesthetic Management Using Multiple Closed-loop Systems and Delayed Neurocognitive Recovery

A Randomized Controlled Trial

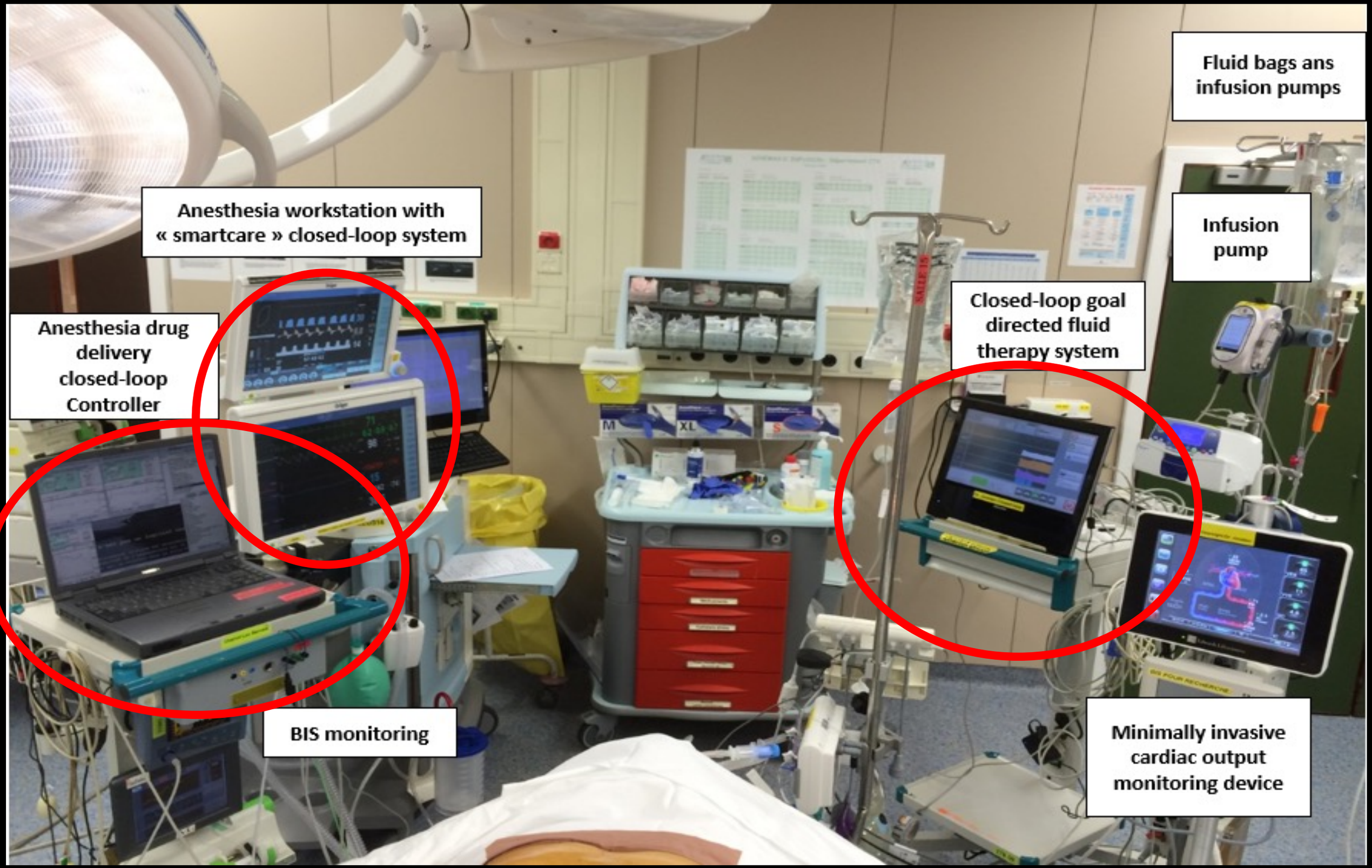
EDITORIALS

Robots Will Perform Anesthesia in the Near Future

Thomas M. Hemmerling, M.D., D.E.A.A.



Joosten et al, ANESTHESIOLOGY 2020


Fluid bags ans infusion pumps
Anesthesia workstation with « smartcare » closed-loop system
Infusion pump
Anesthesia drug delivery closed-loop Controller
Closed-loop goal directed fluid therapy system
BIS monitoring
Minimally invasive cardiac output monitoring device

- **Background**:

  - Cognitive changes after anesthesia
    concern.

  - We tested the hypothesis that, in p
    automated management of anesth
    ventilation using three independer
    variables.

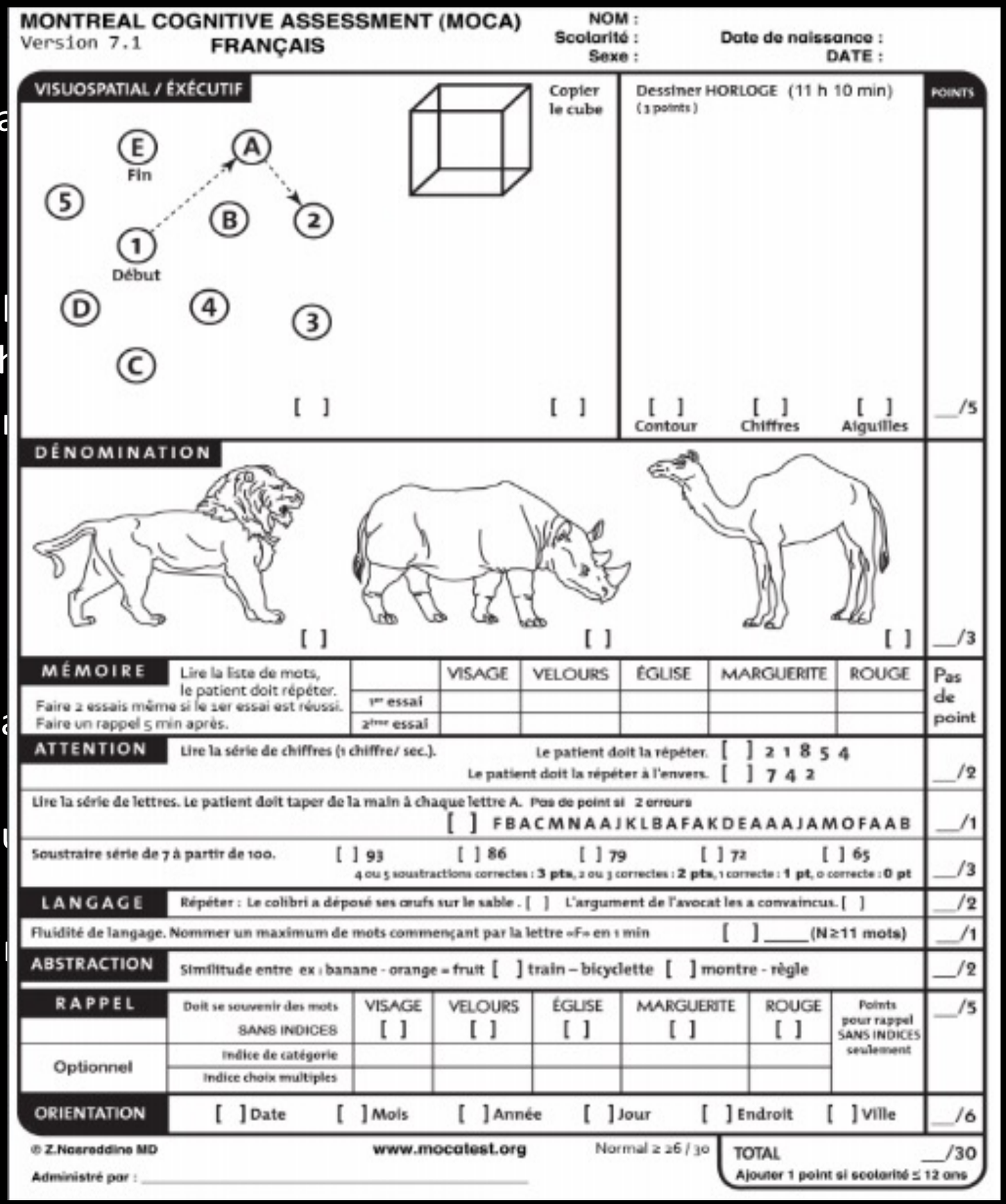
- **Methods:**

  - -Single-center, patient-and-evalua

  - -90 patients having non-cardiac su

  - -Primary outcome was a change i
    Assessment)

  - -Secondary outcomes: battery of
    months post-surgery



MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 FRANÇAIS

NOM :
Scolarité :
Sexe :
Date de naissance :
DATE :

VISUOSPATIAL / ÉXÉCUTIF — Copier le cube — Dessiner HORLOGE (11 h 10 min) (3 points) — POINTS

E Fin, A, 5, B, 2, 1 Début, D, 4, 3, C

[ ] [ ] [ ] Contour [ ] Chiffres [ ] Aiguilles /5

DÉNOMINATION

[ ] [ ] [ ] /3

MÉMOIRE — Lire la liste de mots, le patient doit répéter. Faire 2 essais même si le 1er essai est réussi. Faire un rappel 5 min après.

	VISAGE	VELOURS	ÉGLISE	MARGUERITE	ROUGE	Pas de point
1er essai						
2ème essai						

ATTENTION — Lire la série de chiffres (1 chiffre/ sec.). Le patient doit la répéter. [ ] 2 1 8 5 4 — Le patient doit la répéter à l'envers. [ ] 7 4 2 — /2

Lire la série de lettres. Le patient doit taper de la main à chaque lettre A. Pas de point si 2 erreurs
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B — /1

Soustraire série de 7 à partir de 100. [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 ou 5 soustractions correctes : **3 pts**, 2 ou 3 correctes : **2 pts**, 1 correcte : **1 pt**, 0 correcte : **0 pt** — /3

LANGAGE — Répéter : Le colibri a déposé ses œufs sur le sable . [ ] L'argument de l'avocat les a convaincus. [ ] — /2

Fluidité de langage. Nommer un maximum de mots commençant par la lettre «F» en 1 min [ ] ____ (N≥11 mots) — /1

ABSTRACTION — Similitude entre ex : banane - orange = fruit [ ] train – bicyclette [ ] montre - règle — /2

RAPPEL

	Doit se souvenir des mots	VISAGE	VELOURS	ÉGLISE	MARGUERITE	ROUGE	Points pour rappel SANS INDICES seulement
	SANS INDICES	[ ]	[ ]	[ ]	[ ]	[ ]	
Optionnel	Indice de catégorie						
	Indice choix multiples						

/5

ORIENTATION — [ ] Date [ ] Mois [ ] Année [ ] Jour [ ] Endroit [ ] Ville — /6

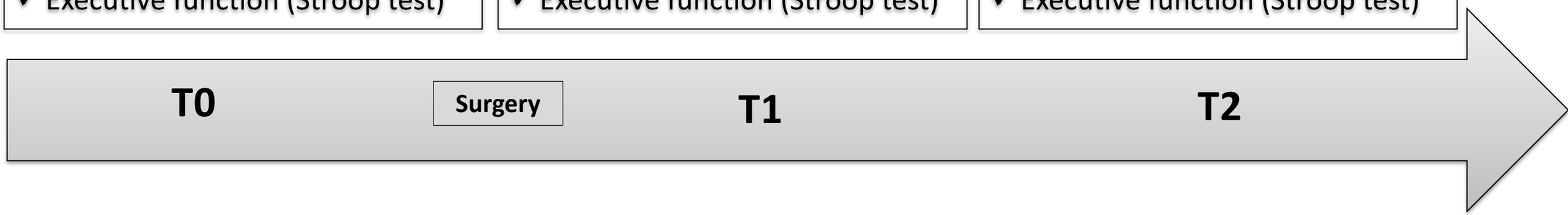
© Z.Nasreddine MD — www.mocatest.org — Normal ≥ 26 / 30

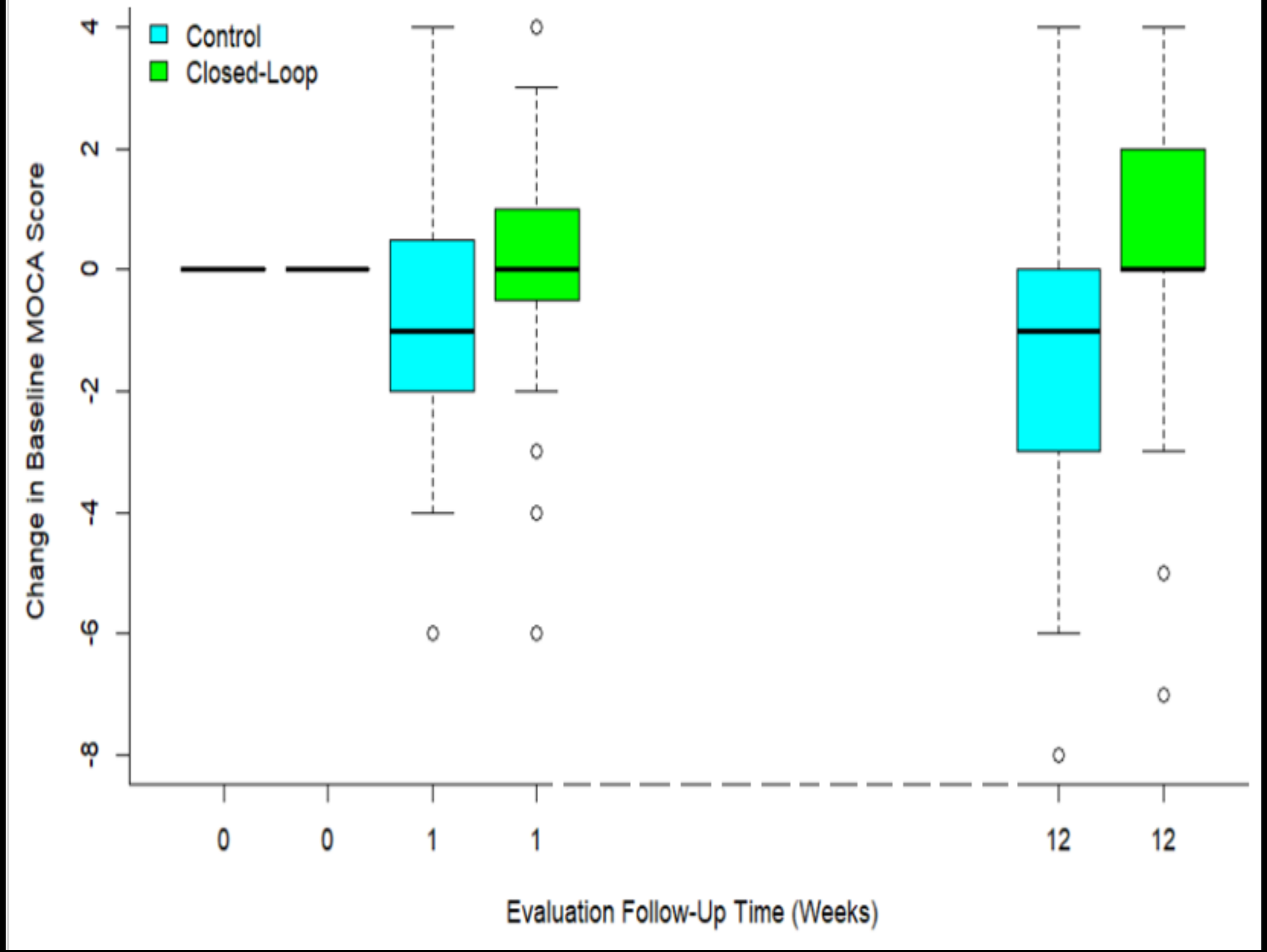
TOTAL /30
Ajouter 1 point si scolarité ≤ 12 ans

Administré par : _____

Figure 1

Preoperative (DAY-1)	Postoperative day 3-7 (POD# 3-7)	Postoperative day 90 (POD# 90)
✓ Edmonton Frailty score ✓ QoR-15 ✓ EQ-5D-5L	✓ QoR-15	✓ EQ-5D-5L
✓ MoCA test	✓ MoCA test	✓ MoCA test
✓ Episodic memory (Free and Cued Selective Reminding Test)	✓ Episodic memory (Free and Cued Selective Reminding Test)	✓ Episodic memory (Free and Cued Selective Reminding Test)
✓ Working memory (Forward and Backward digit spans)	✓ Working memory (Forward and Backward digit spans)	✓ Working memory (Forward and Backward digit spans)
✓ Executive function (Stroop test)	✓ Executive function (Stroop test)	✓ Executive function (Stroop test)




Control
Closed-Loop
Change in Baseline MOCA Score
4
2
0
-2
-4
-6
-8
0
0
1
1
12
12
Evaluation Follow-Up Time (Weeks)

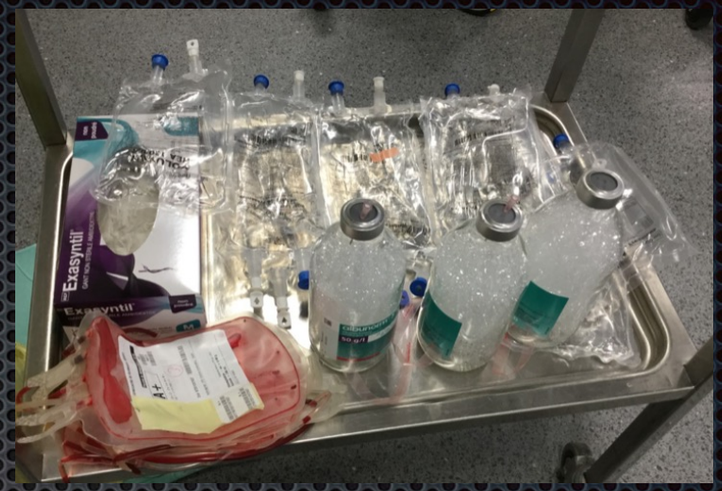
- ✓Automated anesthetic management using the combination of 3 controllers outperforms manual control and may have an impact on delayed neurocognitive recovery.
- ✓However, given the study design, it is not possible to determine the relative contribution of each controller on the cognition score


66
36.5
56


79
37.4
52


79


105
100
14
36
mistral air


Exasyntil


107


Dr. Joosten Closedloop
acer
QOP
AIVOC

dpc4

Pump comms error - attempting restart 1 /3

1. Vasopressor Setup

2. Drip Limits (mcg/min)

3. Patient MAP Target (mmHg)

4. EV-1000 Connection

5. Pump Connection

71

-0.02

P

D

acer

Self-driving Uber kills Arizona woman in first fatal crash involving pedestrian

Tempe police said car was in autonomous mode at the time of the crash and that the vehicle hit a woman who later died at a hospital

Guardian 2.93 Assembly v.1.0.7211.17416

14

Pump Volume Low

Pump volume reserve low

Silence

Setup Alarms

Norepinephrine
16 mcg/ml concentration

Drip Limits (mcg/min)

0 to 25

Target MAP SBP

80

Auto Mode

MAP: 88

Chemyx (3)

Mode Running
Rate 363 ul/min
Total In 48.54
Vol Rem. 1.45

Change

Norepinephrine 5.8 mcg/min

EV-1000 (12)

HR 83
BP 132/61 (88)
SV 98
SW 3

Continuous

Guardian 2.93 Assembly v.1.0.7211.17416

14

Pump Volume Low

Setup | Alarms

Upper Rate Alarm
5 mcg/min

Lower Rate Alarm
0 mcg/min

Rate Change: 2 Min
6 mcg/min

Rate Change: 10 Min
10 mcg/min

Pump volume reserve low

Auto Mode

MAP: 75

Norepinephrine 4.7 mcg/min

Dr. JOOSTEN

Guardian 2.93 Assembly v.1.0.7211.17416

dpc

Monitor Bad Data

Setup Alarms

Vital signs outside nominal ranges; auto mode disabled

Silence

Norepinephrine
16 mcg/ml concentration

Rate Locked

Rate Locked: 7.4 mcg/min

Drip Limits (mcg/min)

0 to 25

Target MAP SBP

75

MAP: 0

Chemyx (3)

Mode Running
Rate 466 ul/min
Total In 23.65
Vol Rem 26.34

Change

Norepinephrine 7.4 mcg/min

EV-1000 (12)

HR 0
BP 0/0 (0)
SV 0
SVV 0

Continuous

Journal of Clinical Monitoring and Computing
https://doi.org/10.1007/s10877-020-00642-4

ORIGINAL RESEARCH

Detection of arterial pressure waveform error using machine learning trained algorithms

Joseph Rinehart[1,4] · Jia Tang[1] · Jennifer Nam[1] · Sophie Sha[1] · Paulette Mensah[1] · Hailey Maxwell[1] · Michael-David Calderon[1] · Michael Ma[1] · Alexandre Joosten[2,3]

Received: 30 June 2020 / Accepted: 29 December 2020

Prospective Clinical Evaluation of a Machine-Learning Trained Algorithm for Detection of Arterial Pressure Transducer Drop

Joseph Rinehart MD [1], Nicholas Pham, Deena Khoury BS, Ishita Srivastava, Paulette Mensah BS[1], Hailey Maxwell BM [1], Sophie Shah MD [1], Michael Ma BS [1], Alexandre Joosten MD PhD [2,3]

INTELLIGENCE-BASED MEDICINE

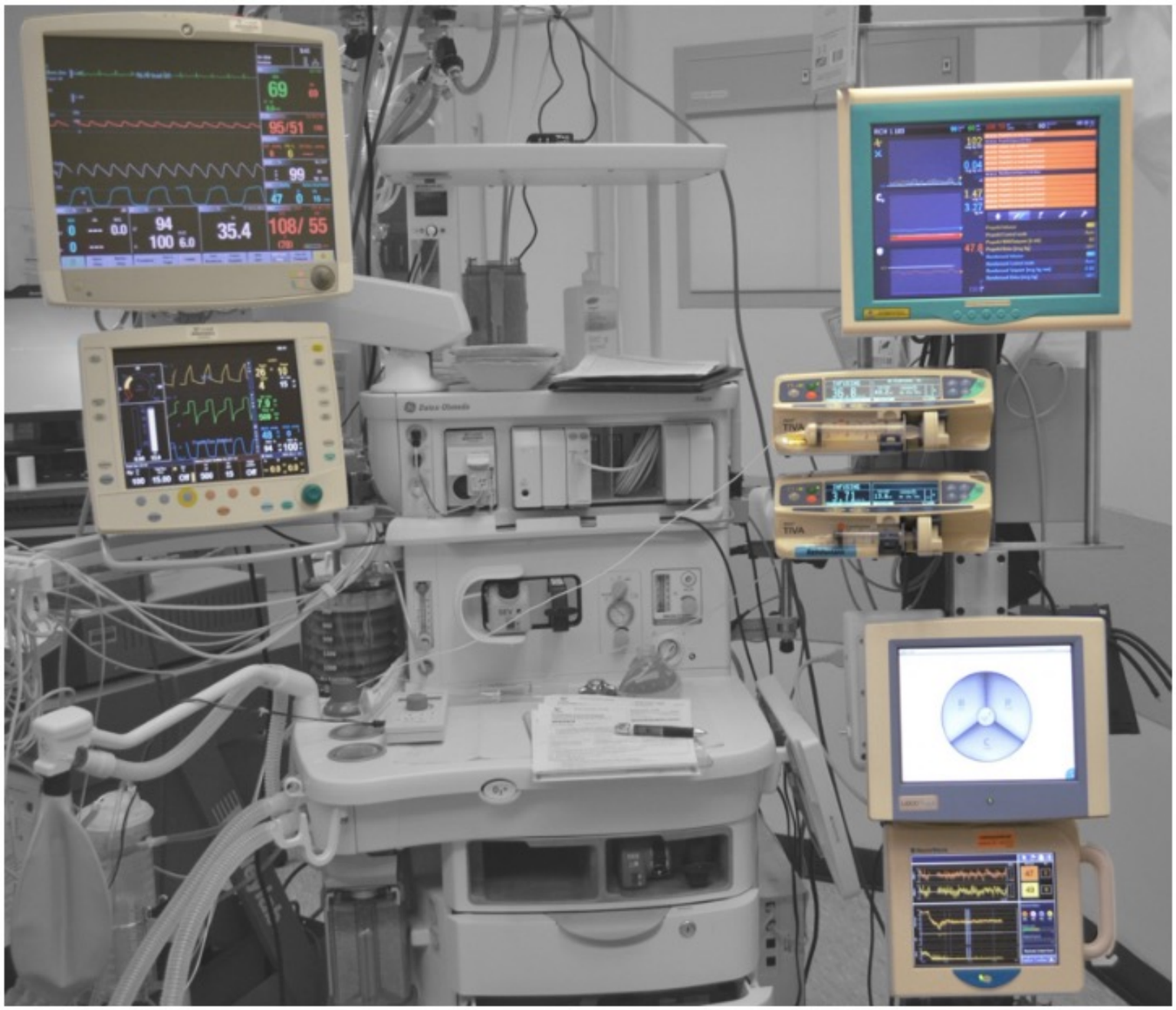
The Washington Post

2015

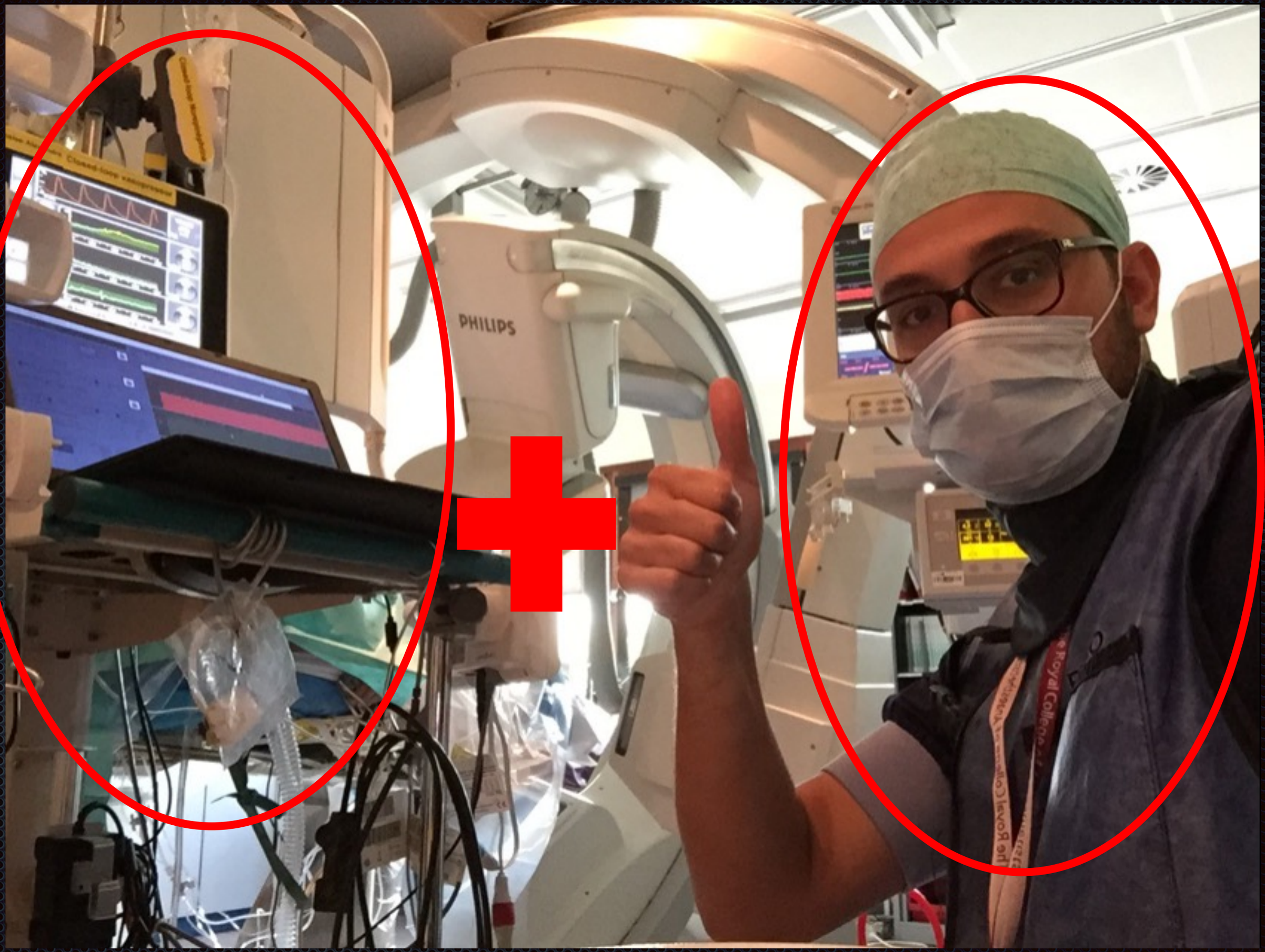
The Switch

‘We are convinced the machine can do better than human anesthesiologists’

By Todd C. Frankel May 15, 2015



The iControl-RP, which fully automates anesthesia for operations, stands on the right. On the left are traditional anesthesia monitors that would be used by a human doctor. UNIVERSITY OF BRITISH COLUMBIA PHOTO


PHILIPS


Technology will not replace the anesthesiologist

We still need a good Anesthetist!

Technology-enhanced simulation training in health care professions education is associated with large effects for outcomes of knowledge, skills, and behaviors! JAMA

Pilots complained about autopilot issues with Boeing jets involved in two deadly crashes

'DON'T SINK! DON'T SINK!'

By Andrew J. Hawkins | @andyjayhawk | Mar 13, 2019, 12:32pm EDT

"Pilots aren't being adequately trained on the autopilot system".