Gli effetti sui gas ematici durante l'ipotermia prolungata.

Pietro Camozzi

Hôpital du Valais
Spital Wallis

Modifiche ai campioni di sangue in vitro

Hôpital du Valais
Spital Wallis

37°C
semplice

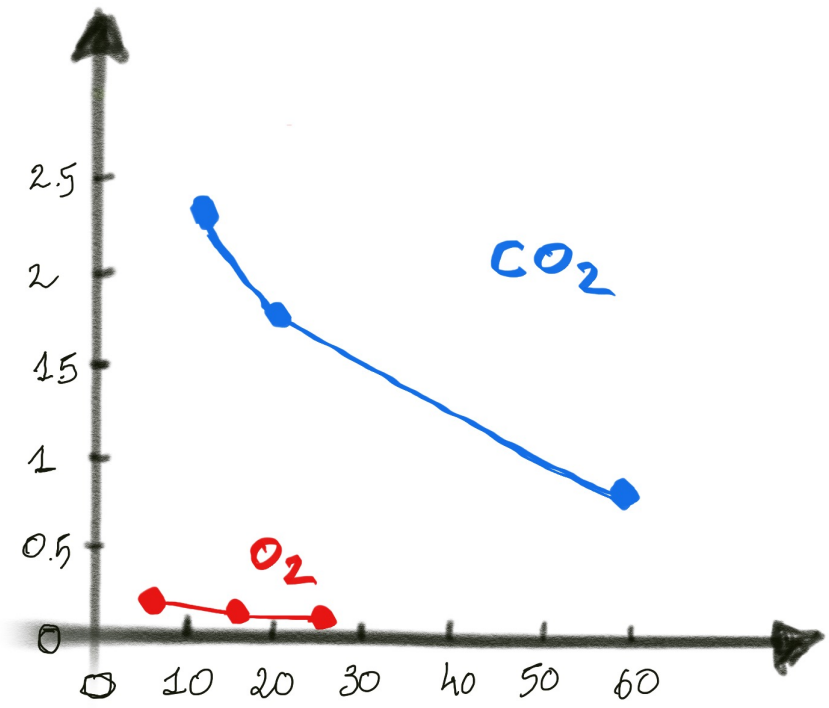
Raffreddamento

- **pH 7.4**
- **pCO2 40 mmHg**
- **pO2 90 mmHg**

contenitore ermetico

- **aumenta**
- **diminuisce**
- **diminuisce leggermente**

Legge di Henry sulla solubilità dei gas



Sol = kH x pG

Hôpital du Valais
Spital Wallis

CLIN. CHEM. 29/11, 1877–1885 (1983)

review

Temperature Correction of Blood-Gas and pH Measurements

Edward R. Ashwood, Gerald Kost, and Margaret Kenny

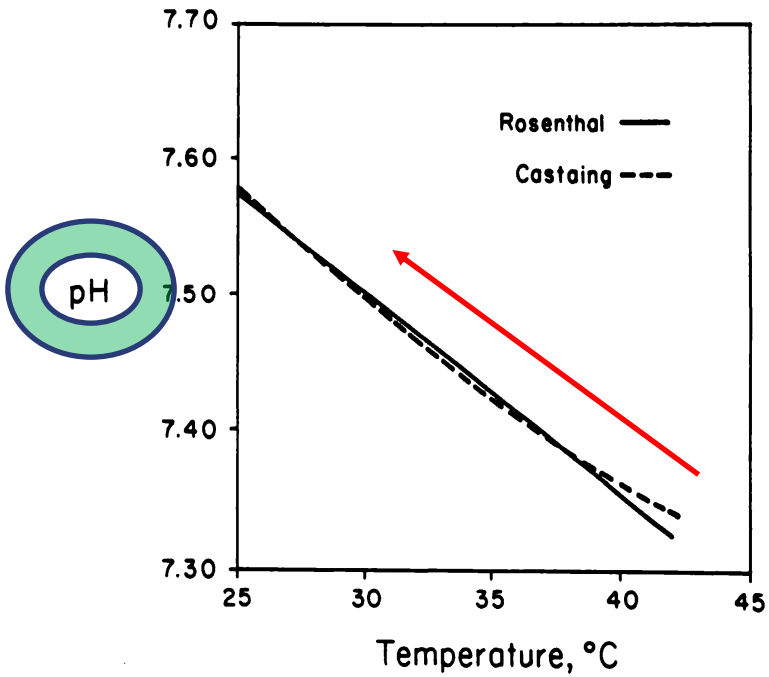


Fig. 1. Temperature corrections for in vitro closed-system pH

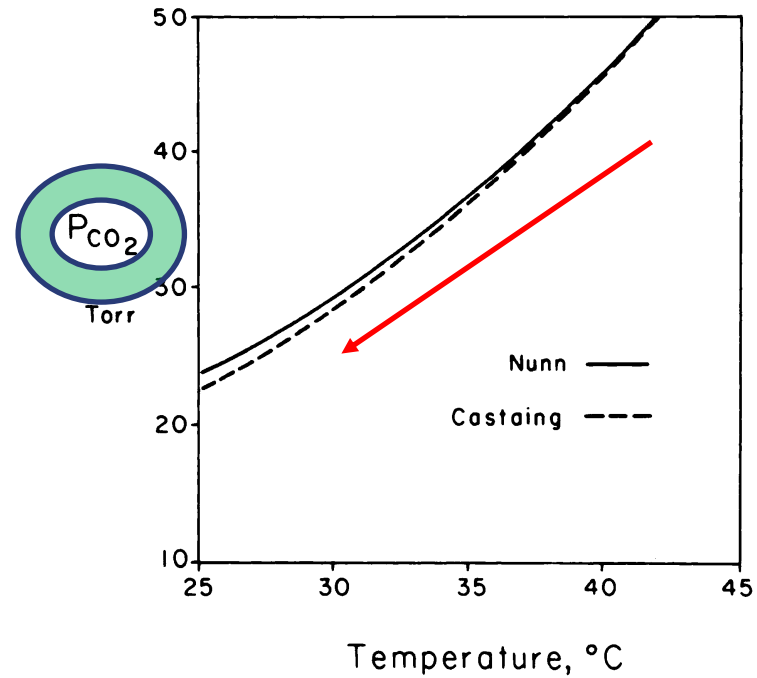
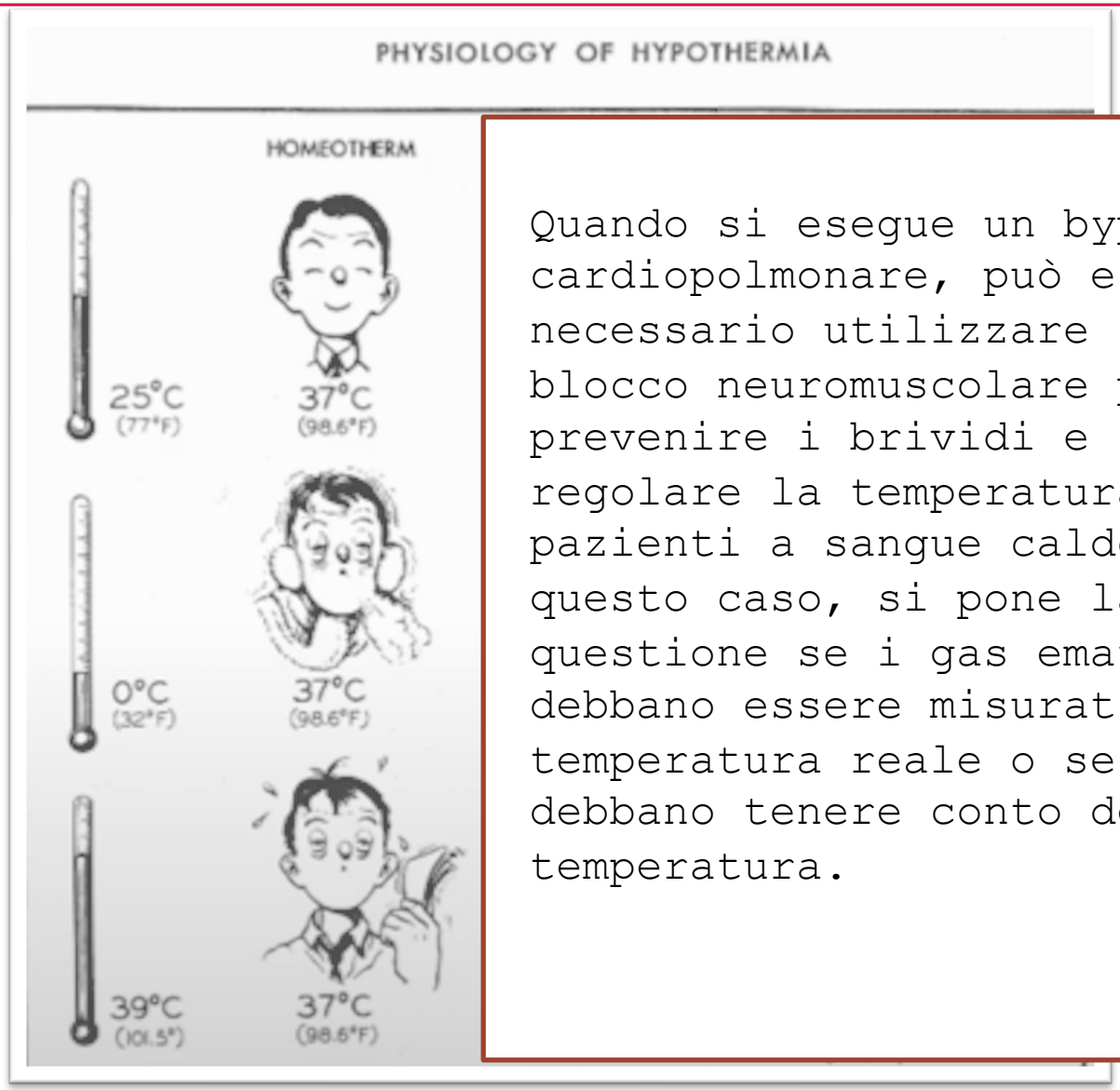


Fig. 2. Temperature corrections for in vitro closed-system p_{CO_2}

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

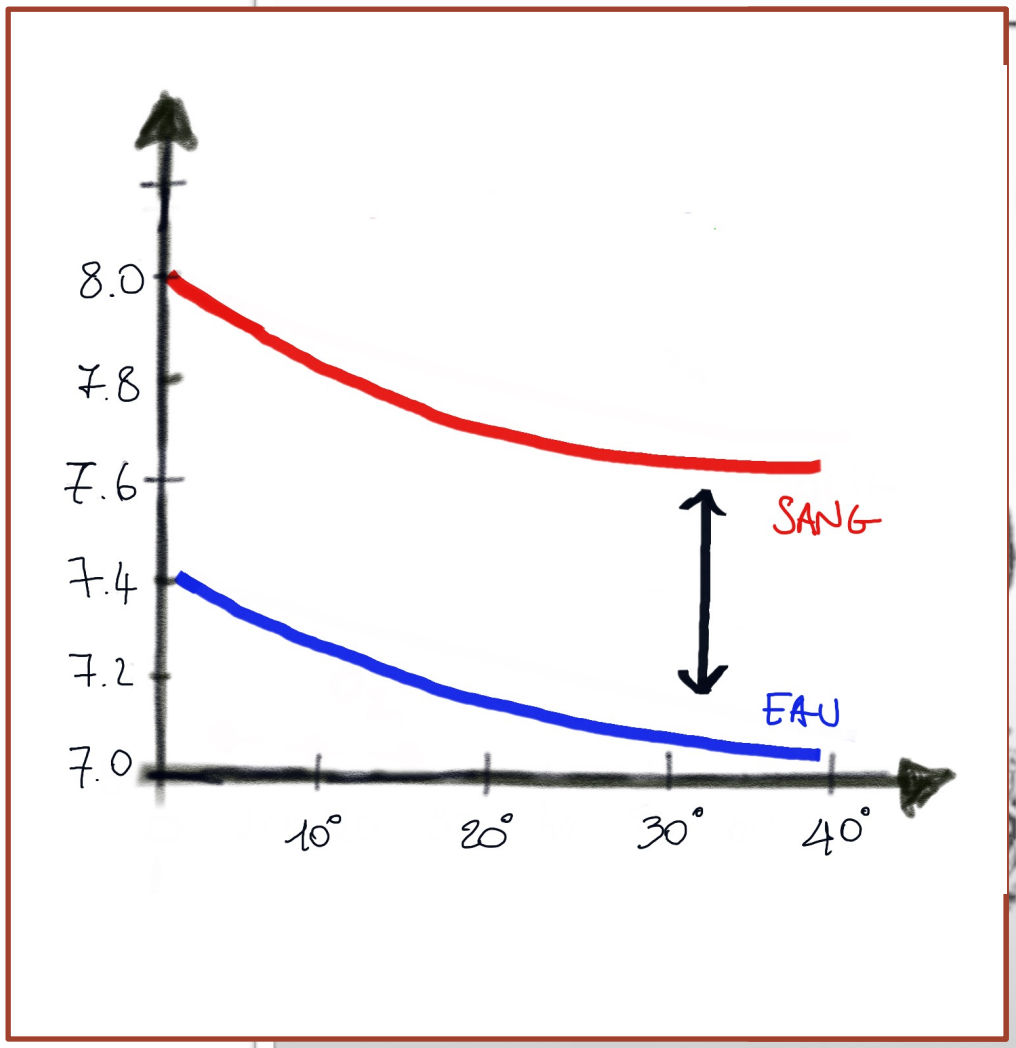
Hôpital du Valais
Spital Wallis

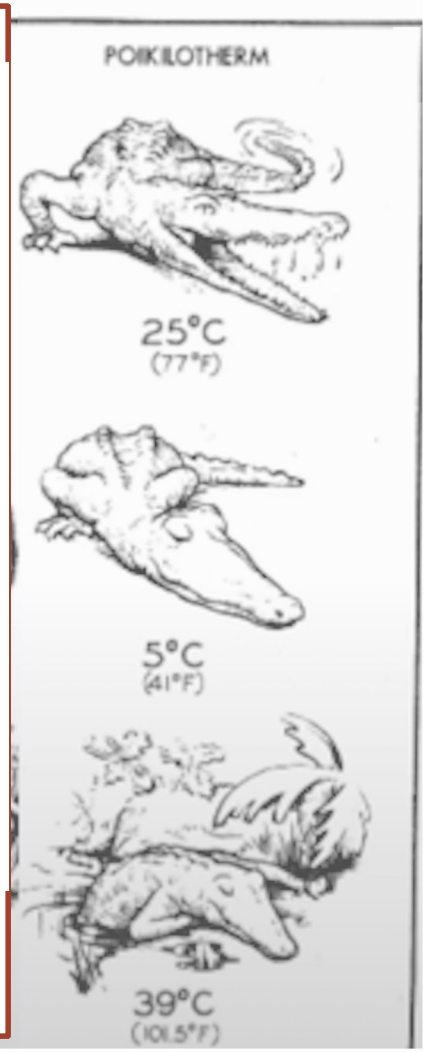
Questo solleva la domanda: è giusto? Vogliamo che la CO2 diminuisca naturalmente con la temperatura o vogliamo mantenere una quota normale di CO2 in questo intervallo di temperature? E questo è il vero problema che discuteremo oggi.



Quando si esegue un bypass cardiopolmonare, può essere necessario utilizzare il blocco neuromuscolare per prevenire i brividi e regolare la temperatura dei pazienti a sangue caldo. In questo caso, si pone la questione se i gas ematici debbano essere misurati alla temperatura reale o se debbano tenere conto della temperatura.

PHYSIOLOGY OF HYPOTHERMIA

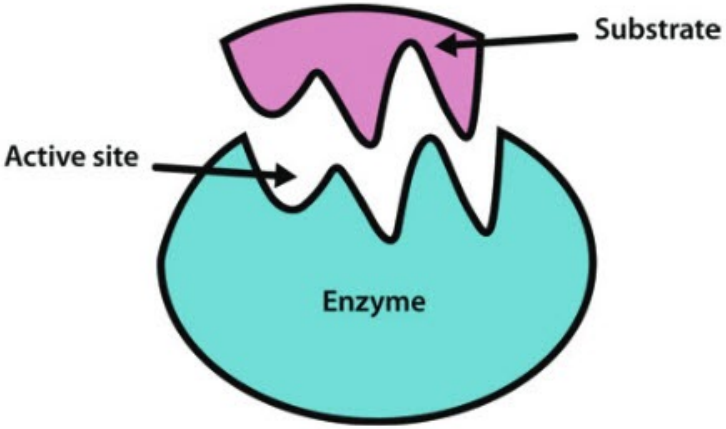


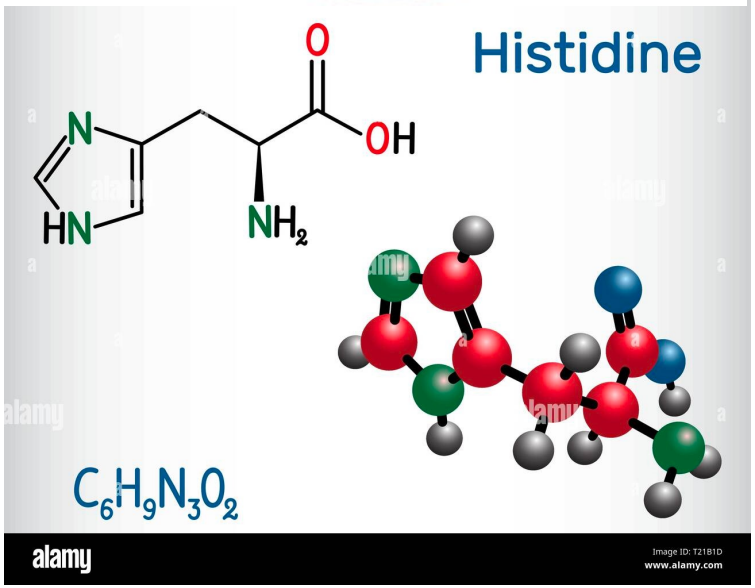


Alpha STAT Rationale

Neutralità H+/OH-

L'imidazolo ha un grado di dissociazione (detto alfa) di 0,55 nel compartimento intracellulare e questo rimane costante nonostante le variazioni di temperatura (cioè il pK non cambia al variare della temperatura).





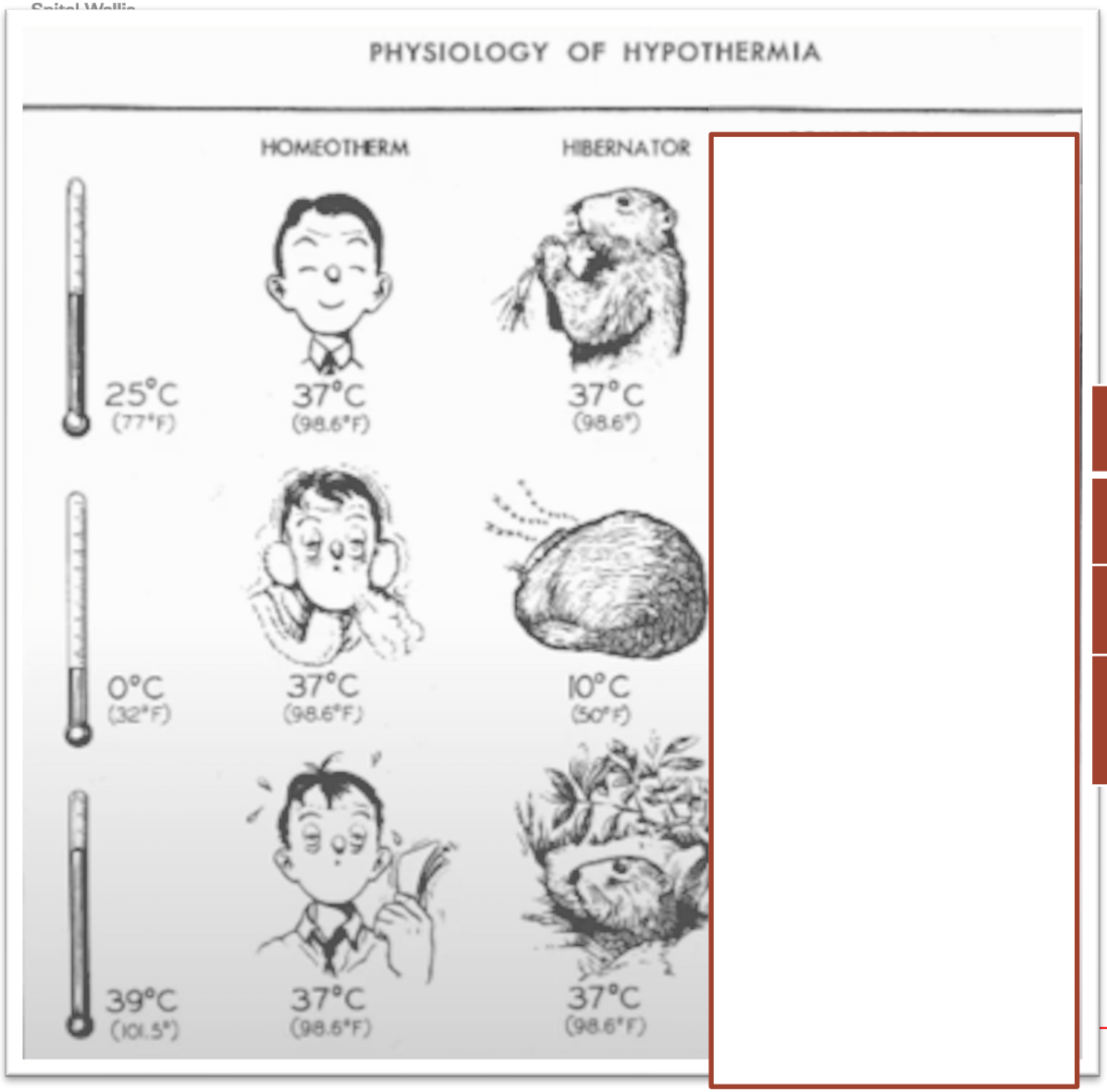
Alpha Stat pro

- Il rapporto costante H+/OH- è l'elemento importante da mantenere per conservare la neutralità [H+] = [OH-].

- Le strutture proteiche normali e la loro funzione, in particolare quella degli enzimi, dipendono da un ambiente elettrochimico costante e neutro, perché gli stati di carica e i legami elettrochimici sono in gran parte responsabili del mantenimento della normale configurazione proteica.

- Mantenimento dell'autoregolazione cerebrale.

pH Stat: pH stabile corretto per la temperatura



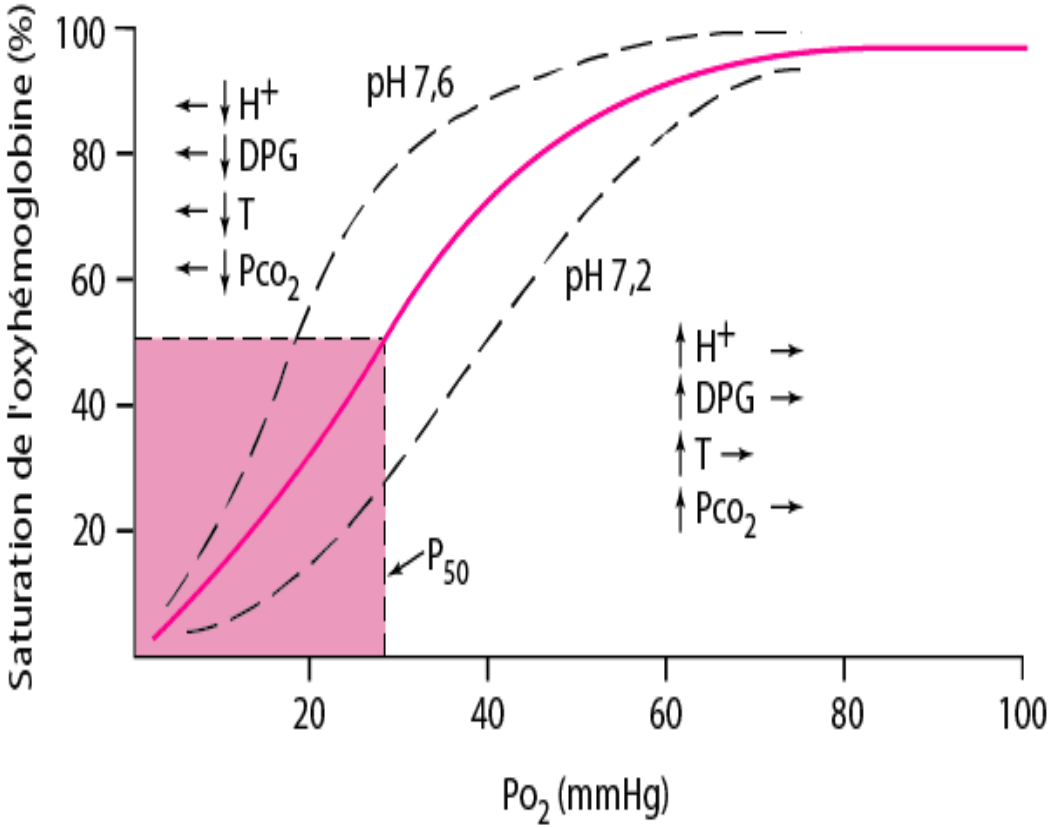
	37°C	Ipotermia
pH	7.40	7.40
P_aCO_2	40 mmHg	↑ Contenuto totale
P_aO_2	90 mmHg	Leggera diminuzione

pH Stat Rationale

- **L'aggiunta di CO2 al circuito mantiene il pH = 7,40**

Può essere utile perché:

- La CO2 può contrastare la curva di dissociazione
- La CO2 è un potente vasodilatatore cerebrale e favorisce un elevato flusso sanguigno cerebrale.
- Raffreddamento più completo e omogeneo.
- Previene il furto cerebrale dovuto ai collateralismi aorto-polmonari.



Riassunto rapido: metodi pH-stat e Alpha-stat

Hôpital du Valais
Spital Wallis

pH-stat

- Obiettivo: mantenere il pH arterioso = 7,40 ad ogni variazione di temperatura.

Campione alla temperatura effettiva del paziente.

- Per raggiungere questo obiettivo, dobbiamo permettere alla CO2 di accumularsi

Alpha-stat

- Obiettivo: mantenere un pH = 7,40

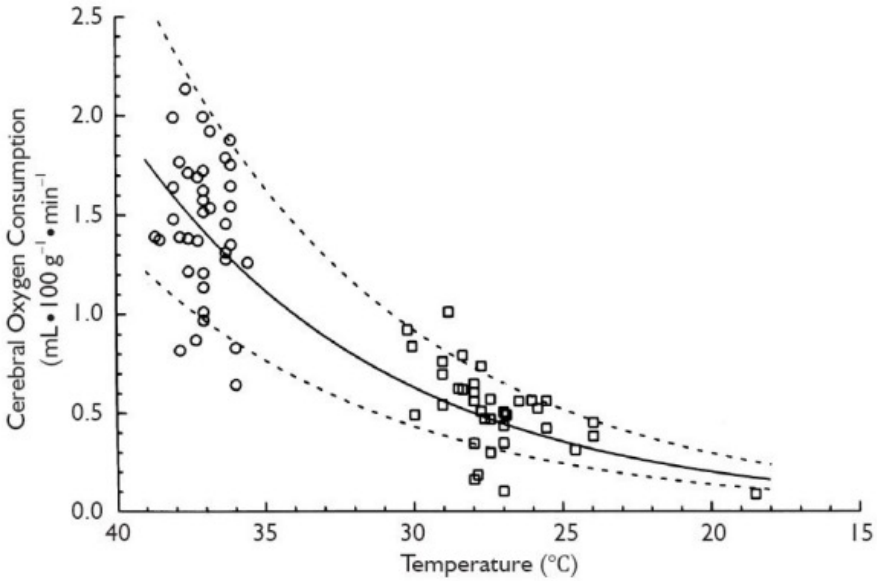
In un CAMPIONE NON CORRETTO per temperatura, per esempio 37°C

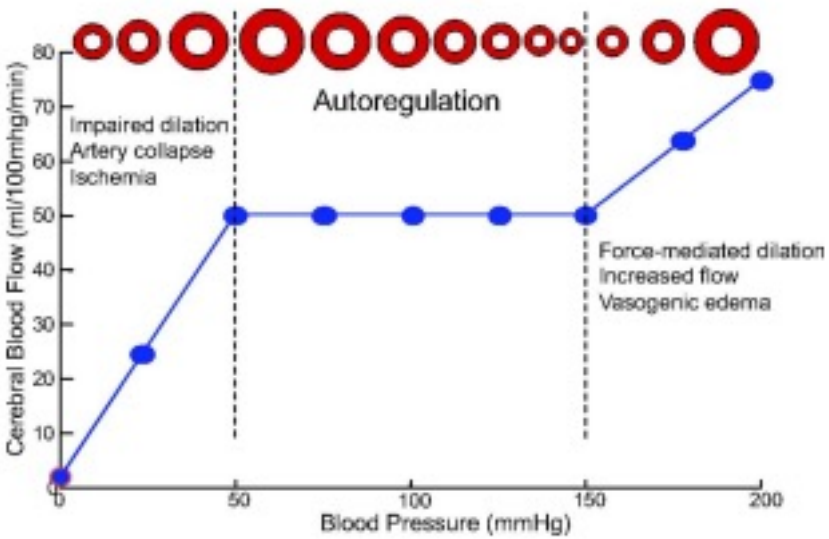
- Tecnicamente facile. Eseguire le normali analisi del sangue sulla base dei risultati dei campioni.

Hôpital du Valais
Spital Wallis

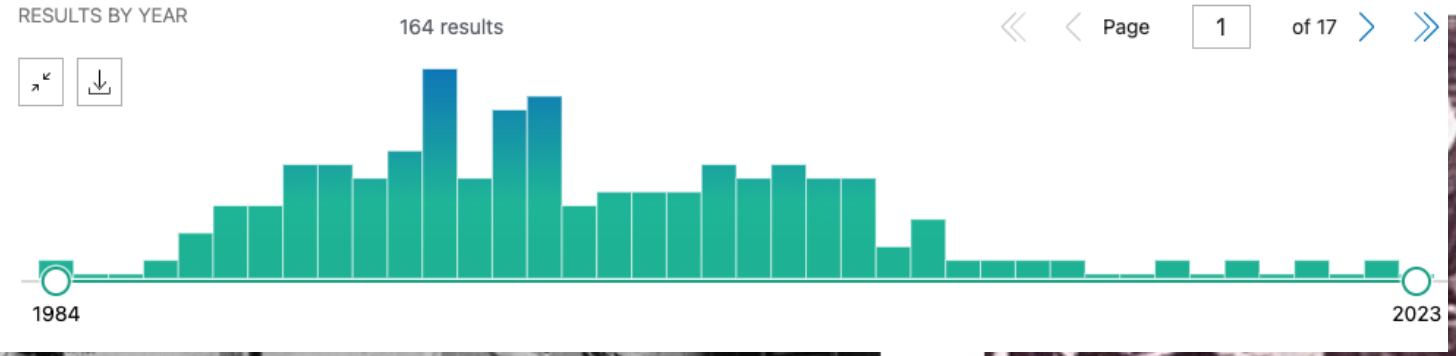
- Il flusso sanguigno cerebrale è strettamente legato alle esigenze metaboliche cerebrali
- È costante in un'ampia gamma di pressioni di perfusione.
- La regolazione autonoma cerebrale è mantenuta in ipotermia moderata
- La regolazione autonomica cerebrale è compromessa nell'ipotermia profonda (<22°C)

- Caduta del tasso metabolico cerebrale con l'ipotermia





Hôpital du Valais



Cardiopulmonary Support and Physiology

An evidence-based review of the practice of cardiopulmonary bypass in adults: A focus on neurologic injury, glycemic control, hemodilution, and the inflammatory response

Kenneth G. Shann, CCP,[a] Donald S. Likosky, PhD,[b] John M. Murkin, MD,[c] Robert A. Baker, PhD CCP(Aust),[d] Yvon R. Baribeau, MD,[e] Gordon R. DeFoe, CCP,[b] Timothy A. Dickinson, MS,[f] Timothy J. Gardner, MD,[g] Hilary P. Grocott, MD,[h] Gerald T. O'Connor, PhD, DSc,[b] David J. Rosinski, CCP,[i] Frank W. Sellke, MD,[j] and Timothy W. Willcox, CCP(Aust)[k]

pH Management

The clinical team should manage adult patients undergoing moderate hypothermic CPB with alpha-stat pH management. (Class I, Level A)

Table 1. Methodologies and policies from the American College of Cardiology/American Heart Association Task Force on Practice Guidelines

Classification of recommendations	Level of evidence
Class I: Conditions for which there is evidence, general agreement, or both that a given procedure or treatment is useful and effective	Level A: Data derived from multiple randomized clinical trials
Class II: Procedure-treatment should be performed-administered	Level B: Data derived from a single randomized trial or nonrandomized studies
Class IIA: Additional studies with focused objectives needed	Level C: Consensus opinion of experts
Class IIB: Additional studies with broad objectives needed; additional registry data would be helpful	
Class III: Procedure-treatment should not be performed-administered because it is not helpful and might be harmful	

Adapted from Eagle KA, Guyton RA, Davidoff R, et al, ACC/AHA 2004 Guideline Update for Coronary Artery Bypass Graft Surgery: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1999 Guidelines for Coronary Artery Bypass Graft Surgery): 2004.

Fig 5. The patient is currently submerged in an ice bath. Courtesy of the US National Library of Medicine.

John Gibbon and his wife Mary Hopkinson developing the first heart-lung machine.

Hôpital du Valais
Spital Wallis

CARDIOTHORACIC ANESTHESIOLOGY:
The Annals of Thoracic Surgery CME Program is located online at http://www.annalsthoracicsurgery.org/cme/home. To take the CME activity related to this article, you must have either an STS member or an individual non-member subscription to the journal.

Deep Hypothermic Circulatory Arrest Effectively Preserves Neurocognitive Function

Katherine H. Chau, AB, Tamir Friedman, MD, Maryann Tranquilli, RN, and John A. Elefteriades, MD

Section of Cardiothoracic Surgery and Department of Diagnostic Imaging, Yale University School of Medicine, New Haven, Connecticut

DEVELOPMENTAL AND NEUROLOGIC EFFECTS OF ALPHA-STAT VERSUS PH-STAT STRATEGIES FOR DEEP HYPOTHERMIC CARDIOPULMONARY BYPASS IN INFANTS

The Journal of Thoracic and Cardiovascular Surgery

David C. Bellinger, PhD, MSc[a]
David Wypij, PhD[e]
Adre J. du Plessis, MBChB, MPH[a]
Leonard A. Rappaport, MD[b]
James Riviello, MD[a]
Richard A. Jonas, MD[c]
Jane W. Newburger, MD, MPH[d]

CPB was associated with a trend toward lower postoperative morbidity and with a significantly shorter recovery time to first EEG activity.[6] The current study explored the effect of pH management strategy on longer term developmental outcome in the same study cohort. We found that infants randomized to the pH-stat and alpha-stat methods of pH management did not differ significantly at 1 year of age in their scores on the Bayley Scales of Infant Development or in their neurologic examination. Similarly, at 2 to 4 years of age, the treatment groups had similar development, as assessed by parental responses to mailed questionnaires, including the Child Development Inventory and the Child Behavior Checklist.

Is α-Stat or pH-Stat the Best Strategy During Hypothermia After Cardiac Arrest?*

Cornelia Hoedemaekers, MD, PhD
Johannes G. van der Hoeven, MD, PhD
Department of Intensive Care
Radboud University Nijmegen Medical Centre
Nijmegen, The Netherlands

The post–cardiac arrest syndrome includes post–cardiac arrest brain injury, post–cardiac arrest myocardial dysfunction, the systemic ischemia/reperfusion response, and the persistent precipitating disease. Changes in macro- and microcirculatory flow, combined with activation of the innate and adaptive immune system, are the major pathophysiological features of this syndrome. Changes in Pa_{CO_2} may interact with this complex interplay of events at several levels. Profound dyscarbia should be avoided. It remains difficult and perhaps impossible to establish at the bedside how smaller changes in pH and Pa_{CO_2} induced by a pH-stat or α-stat strategy at different moments in time will affect the risk of secondary brain damage and prognosis in patients after cardiac arrest.

Hôpital du Valais
Spital Wallis

INTERACTIVE
CARDIOVASCULAR AND
THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 10 (2010) 271-282

www.icvts.org

Best evidence topic - Cardiopulmonary bypass

Is pH-stat or alpha-stat the best technique to follow in patients undergoing deep hypothermic circulatory arrest?

Khairul Anuar Abdul Aziz*, Ayo Meduoye

Department of Cardiothoracic Surgery, Glenfield Hospital, Leicester, LE3 9PQ, UK

In conclusion, there is evidence to suggest that the best technique to follow in the management of acid-base in patients undergoing deep hypothermic circulatory arrest during cardiac surgery is dependent upon the age of the patient with better results using pH-stat in the paediatric patient and alpha-stat in the adult patient.

Hôpital du Valais
Spital Wallis

Hyperoxia for Management of Acid-Base Status During Deep Hypothermia With Circulatory Arrest

Jeffrey M. Pearl, MD, Donald W. Thomas, CCP, Gary Grist, CCP, Jodie Y. Duffy, PhD, and Peter B. Manning, MD

Children's Hospital Medical Center, Cincinnati, Ohio, and Children's Mercy Hospital, Kansas City, Missouri

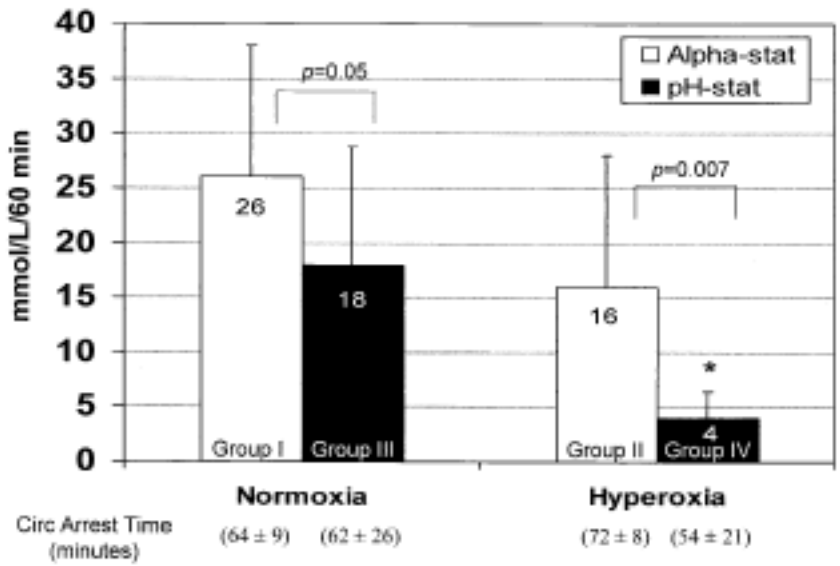


*Fig 3. Acid production corrected for the time of circulatory arrest in normoxic and hyperoxic patients. Patients treated with hyperoxia before deep hypothermic circulatory arrest had less acid generation during deep hypothermic circulatory arrest than their respective normoxic cohorts. Patients in group IV (pH-stat and hyperoxia) had only 25% as much acid generation during 60 minutes of bypass than the next closest group. (*p < 0.05 compared with groups I through III.)*

Results. **Both hyperoxia groups had less acidosis after deep hypothermic circulatory arrest than normoxia groups. Group IV had less acid generation during circulatory arrest and less base excess after arrest than groups I, II, or III ($p < 0.05$). Group IV produced only 25% as much acid during deep hypothermic circulatory arrest as the next closest group (group II).**

Conclusions. **Hyperoxia before deep hypothermic circulatory arrest with α-stat or pH-stat strategy demonstrated advantages over normoxia. Furthermore, pH-stat strategy using hyperoxia provided superior venous blood gas values over any of the other groups after circulatory arrest.**