Thomas G. Wharton

Memorial Lecture

D. Scott Lawson
American Academy of Cardiovascular Perfusion
January 25, 2014

Thomas G. Wharton

A Non-Perfusionist who donated $2,000 in 1979 to start the AACP

- Facilitator, gentleman, shunned the spotlight, visionary, dedicated, professional

- Served as the first Executive Director of the Journal of Extracorporeal Technology
- The Executive Director of the American Society of Extracorporeal Technology
- The Executive Director of the American Board of Cardiovascular Perfusion.

In Memoriam

Thomas Groth Wharton
April 30, 1934–March 19, 1980

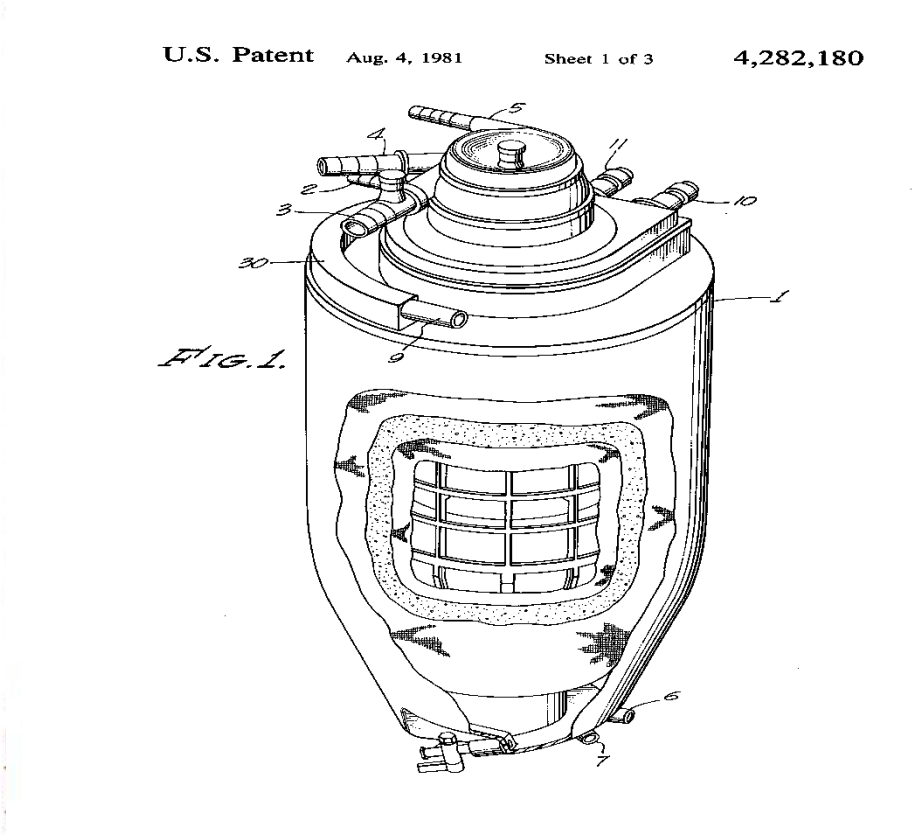
As word came of the untimely death of Tom Wharton a solemn stillness suddenly entered into our lives and hence an empty void began. A life of dedication had quietly passed from our midst. Whether it was as a representative of industry, or society management or as publisher of this journal he was supportive of AmSECT programs, their implementation and their total project involvement. His involvement was in a variety of activities with an inability to say 'no'.

The privilege of serving AmSECT was Tom's, or he would have you thought it so. It was not always our ability as a Society to make a project work, but his availability. For those of us who knew and worked with him, we were the recipients of his unique gift of service. He could recall specific likes and dislikes–always alert to detect and meet our needs. He was genuine. There was a willingness to let others have the credit for his labors. He demonstrated service at it's ultimate level.

Emily Taylor, JECT Editor

Thomas Wharton 1934 - 1980

- 1953 – 1st successful cardiac operation using CPB



Mass produced, disposable bubble oxygenators

Building on Innovation

Congenital Heart Surgery

Objectives:

- Examine advances in cardiopulmonary bypass over the past 30+ years
  - Primarily, pediatric congenital heart surgery
  - Secondarily, adult acquired heart disease as well
- Illustrate the decrease in morbidity and mortality over the past 30+ years
- Illustrate how we have built upon the advances of those who have gone before us to achieve these results

Membrane Oxygenators

- Early 1980's – Membrane oxygenators become available

Kirklin JK, Westaby S, Blackstone EH, Kirklin JW, Chenoweth DE, Pacifico AD. Complement and the damaging effects of cardiopulmonary bypass. J Thorac Cardiovasc Surg 1983;86:856–7.

SIRS—The Systemic Inflammatory Response Syndrome After Cardiac Operations

Kenneth M. Taylor, FRCS

Department of Cardiac Surgery, Royal Postgraduate Medical School, Hammersmith Hospital, London, England

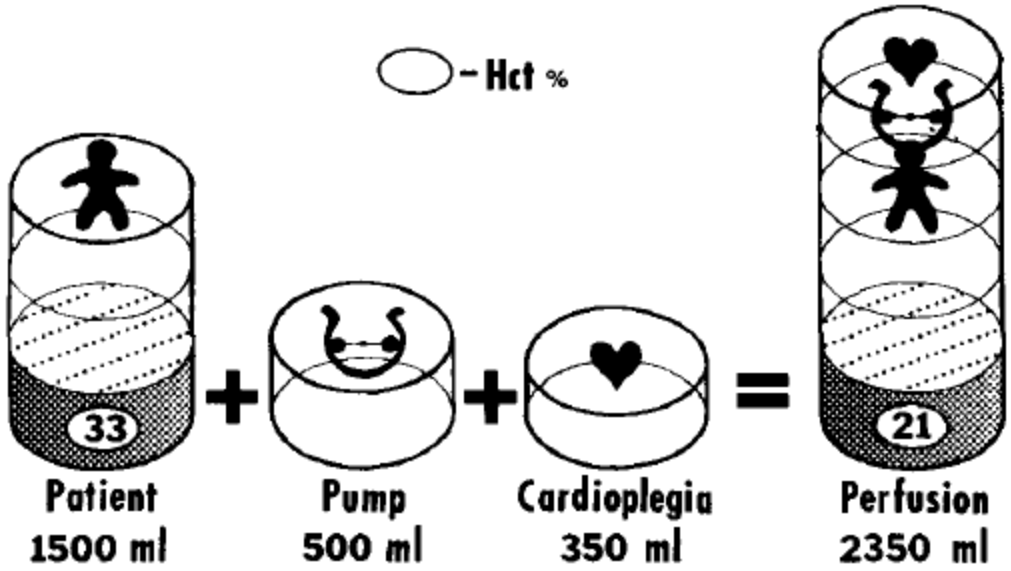
Ann Thorac Surg 1996;61:1607–8

The questions for us must surely be the following: Is cardiac operation per se one of those "severe clinical insults" leading to SIRS? Is SIRS the *inevitable result* of a cardiac operation or is it seen only in particular patient groups? Is the *pattern of the response* in cardiac surgical patients the same as or different from the SIRS pattern generally described?

Circuit miniaturization

Limited Prime Pediatric Perfusion

C. W. Scott, C.C.P., S. Subramanian, M.D.
Chief, Div. of Cardiovascular Surgery,
The Department of Cardiovascular Surgery,
Children's Hospital,
Buffalo, New York



The Journal of Extra-Corporeal Technology Volume 12, Number 1, 1980

Perfusion 1993; **8**: 81–86

Minimizing the bypass circuit: a rational step in the development of paediatric perfusion

Martin Elliott The Hospital for Sick Children, Great Ormond Street, London

Long-term solutions

This solution requires the total rethinking of the current bypass circuit. Why should the pump heads be so near the floor? Why should the pump not be incorporated into an oxygenator/reservoir complex? Why should the suckers not be vacuum-

controlled and demand-triggered?

Perfusion 1994; **9**: 349–355

D-901 neonatal oxygenator: a new perspective

F De Somer Department of Perfusion, **K François** Department of Cardiac Surgery, **L Foubert, Y Deryck** Department of Anaesthesia, **D De Smet, M Vanackere** Department of Perfusion and **G Van Nooten** Department of Cardiac Surgery, University Hospital Gent

We conclude that the D-901 oxygenator opens new perspectives for perfusion in small babies in terms of priming volume and use of homologous blood products while maintaining good gas transfer characteristics. However, larger series are necessary to expand our experience with this device and its limitations.

A Modification of the Sarns Conducer Heat Exchanger as a Low Prime Pediatric Cardioplegia System

Ronald Gorney, PA-C, CCP, Jorge Molina, PA-C, CCP, Timothy Reynolds, BSN

Pediatric Cardio-Thoracic Surgery Associates, Children's Medical Center of Dallas, Dallas, Texas and Memorial Hospital, Colorado Springs, Colorado

THE JOURNAL OF EXTRA-CORPOREAL TECHNOLOGY

Volume 26, Number 1, 1994

Experimental Use of an Ultra-Low Prime Neonatal Cardiopulmonary Bypass Circuit Utilizing Vacuum-Assisted Venous Drainage

Edward Darling, BS, CCP; David Kaemmer, BS, CCP; Scott Lawson, BS, CCP; Greg Smigla, CCP; Kevin Collins, BSN, CCP; Ian Shearer, BS, CCP; James Jaggers, MD

Perfusion Services, DHN, Box 3082, Duke University Medical Center, Durham, North Carolina

THE JOURNAL OF EXTRA-CORPOREAL TECHNOLOGY
Volume 30, Number 4, December 1998

Much work remains to be done, including comparative studies between conventional gravity versus VAVD systems to evaluate a full spectrum of effects that this promising technique may have in neonatal CPB. These initial trials demonstrate that this technique is indeed feasible in a neonatal application and may help usher in the era of non-transfusion neonatal cardiac surgery.

JECT. 2009;41:220–225
The Journal of ExtraCorporeal Technology

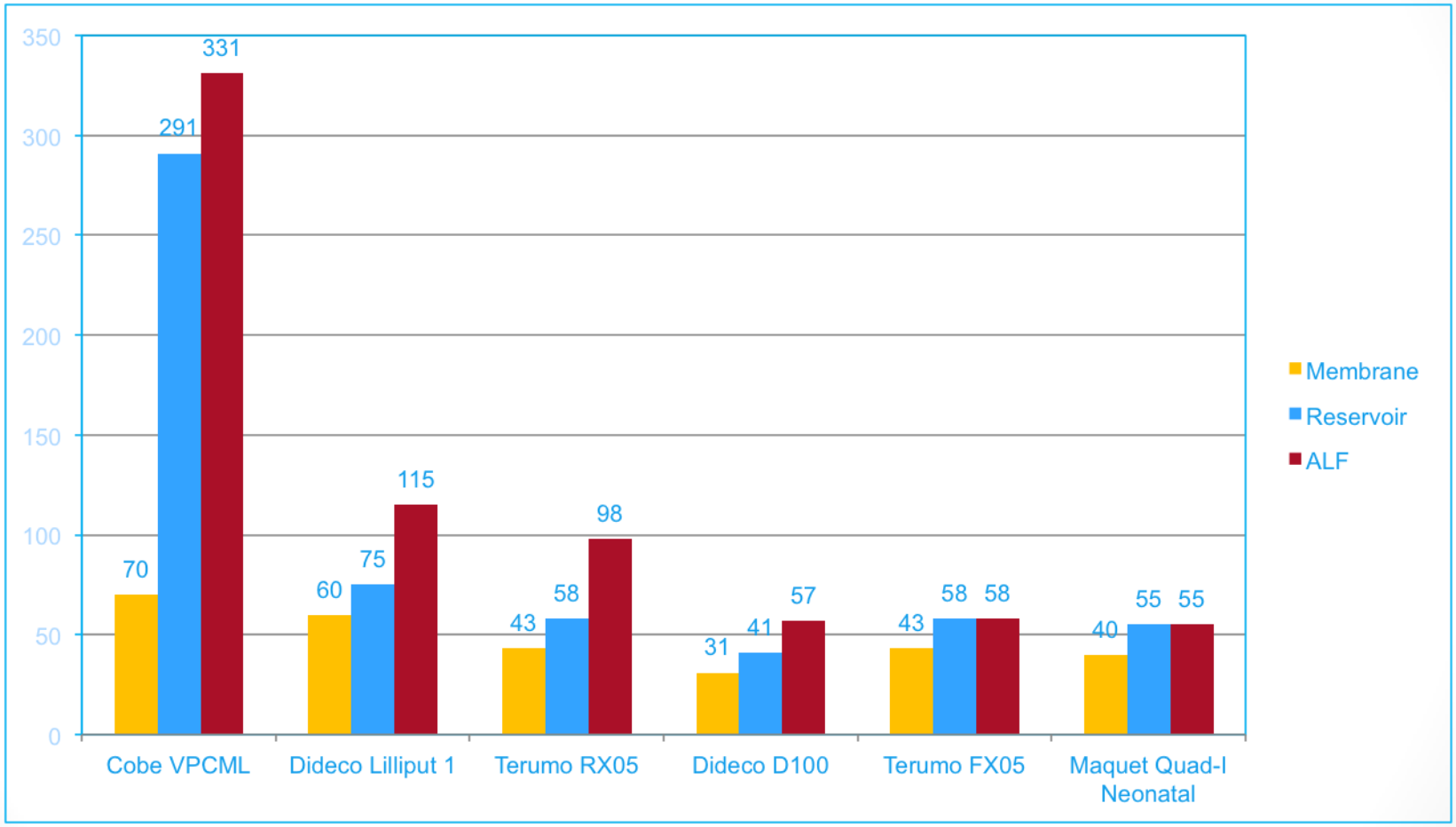
Clinical Evaluation of the Terumo Capiox® FX05 Hollow Fiber Oxygenator with Integrated Arterial Line Filter

Joseph Deptula, MS, CCP; Melinda Valleley, MS, CCP; Kimberly Glogowski, MS, CCP; John Detwiler, BS, RRT; James Hammel, MD; Kim Duncan, MD

Department of Cardiothoracic and Vascular Surgery, Children's Hospital and Medical Center, Omaha, Nebraska

In conclusion, incorporating the Terumo Baby FX05 into our perfusion practice for patients <10 kg has allowed us to significantly reduce our CPB prime volumes and surface area while reducing our blood donor exposure, all without compromising patient safety.

Neonatal oxy prime volume

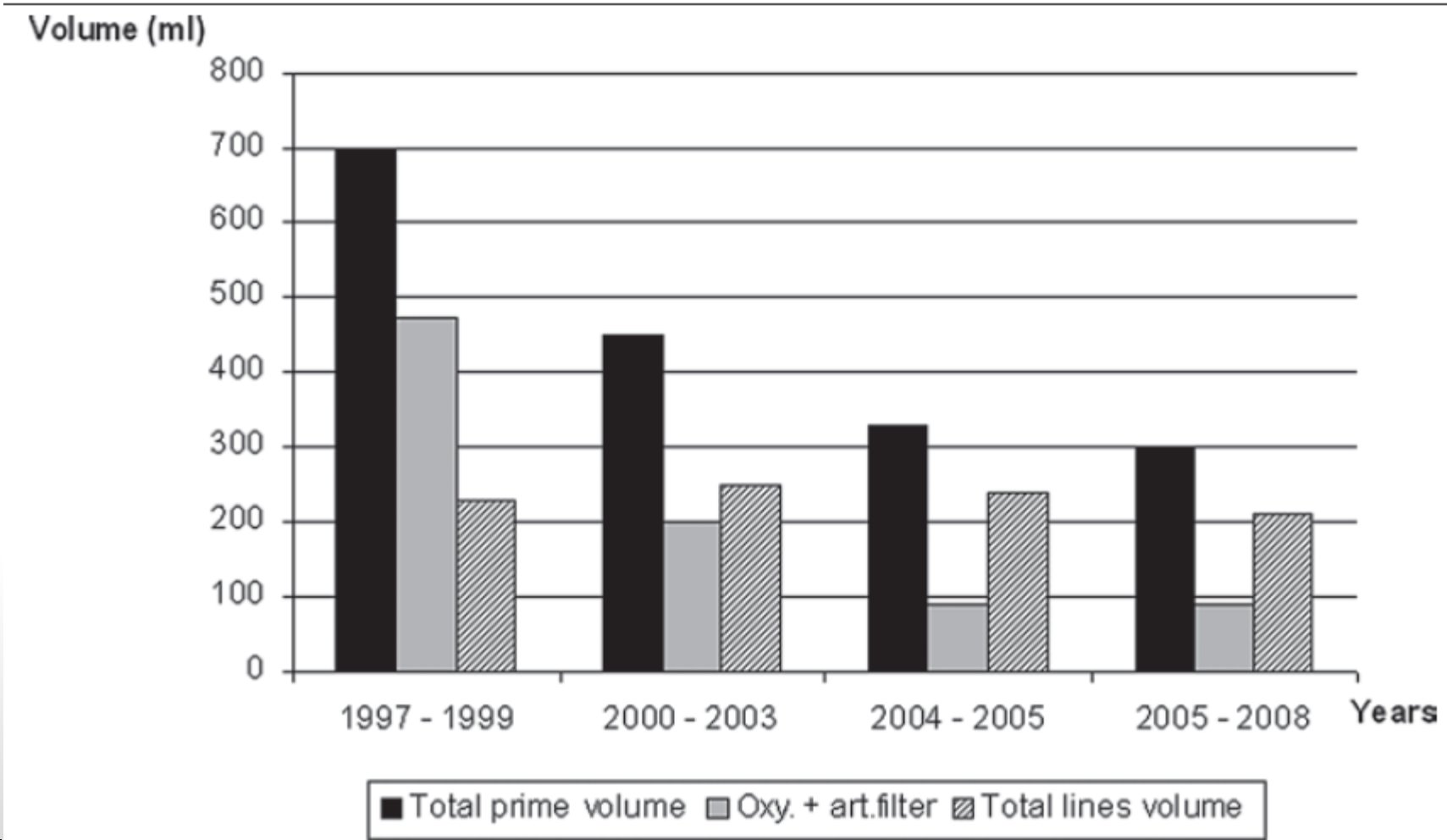


1985 1993 2002 2008 2009 2011

Specific requirements for bloodless cardiopulmonary bypass in neonates and infants; a review

Perfusion
25(4) 237–243
2010

Hanna D Golab, Johanna JM Takkenberg, Ad JJC Bogers



JECT. 2009;41:28–31
The Journal of ExtraCorporeal Technology

Optimizing Circuit Design Using a Remote-mounted Perfusion System

Bradley Kulat, CCP, LP; Neale Zingle, CCP, LP

Children's Memorial Hospital, Chicago, Illinois

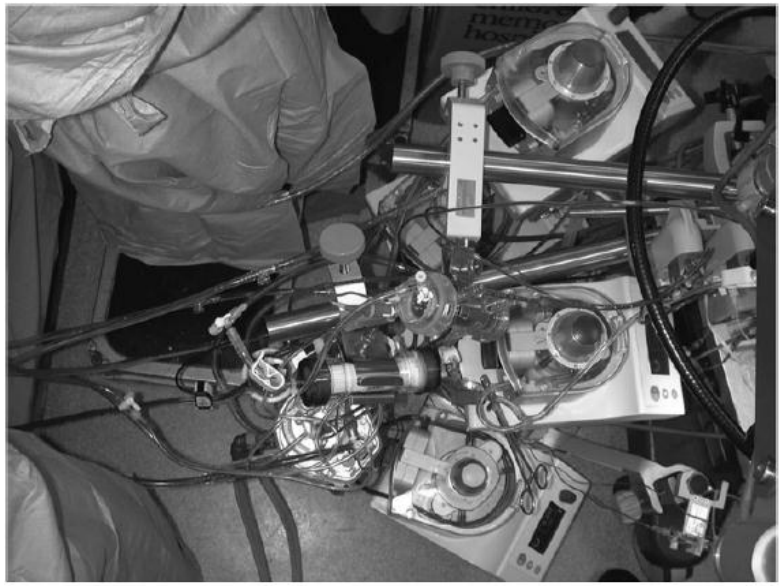


Figure 1. Remote-mounted pump system in close proximity to patient.

In conclusion, using a remote mounted perfusion system resulted in reducing priming volumes and also significantly decreased the need for banked blood, subsequently saving the patient excessive exposure to banked blood.

Other methods of amelioration

Perfusion 1991; 6: 41–50

A successful modification of ultrafiltration for cardiopulmonary bypass in children

SK Naik, A Knight and **MJ Elliott** The Hospital for Sick Children, Great Ormond Street, London

Conclusion

The modified method of ultrafiltration described in this study was superior to conventional ultrafiltration in terms of reduction of the water accumulation associated with CPB. It also permitted the definition of a particular Hct postbypass. Thus, the method has major implications for bypass management and for the requirement for stored blood during and after cardiac surgery in children. Further randomized prospective assessment of the method is required in order to establish this method's safety, efficacy and applicability in children undergoing open-heart surgery. Such assessment is currently being undertaken in our unit.

Perfusion 1993; **8**: 49–54

The effects of bypass on the developing brain

Frank H Kern, William J Greeley and **Ross Ungerleider** Duke University Medical Center, North Carolina

The use of deep hypothermic cardiopulmonary bypass (CPB) with or without total circulatory arrest (TCA) has substantially improved operating conditions for children undergoing congenital heart surgery, resulting in improved survival and reduced cardiac morbidity. As overall surgical outcome has improved, neuropsychiatric dysfunction has become a more prominent and visible complication of the congenital heart patient. Recent reports suggest that transient and permanent neuropsychiatric injuries occur in as many as 25% of all infants undergoing hypothermic CPB with or without TCA.[1] This uncomfortably high incidence of neuropsychiatric impairment is becoming a major focal point for current research into the mechanism of cerebral injury during CPB. Currently the most effective means of protecting the brain from CPB- or TCA-induced injury is hypothermia.[2–6]

Perfusion 1995; **10**: 245–248

Regional cerebral oxygenation during cardiopulmonary bypass*

Ronald R Baris, Andrew L Israel, David W Amory and **Paul Benni** Departments of Anesthesia and Perfusion, Robert Wood Johnson University Hospital, New Brunswick, and Department of Biomedical Engineering, Rutgers University, Piscataway, New Jersey

A significant number of patients suffer transient neuropsychological dysfunction after coronary artery bypass graft (CABG) surgery. Recent studies have implicated reduced levels of O_2 supply/demand ratio during the rewarming phase of cardiopulmonary bypass (CPB). Using a near infrared spectroscopy (NIRS) system that permits continuous noninvasive monitoring of regional cerebral O_2 saturation (rSO_2), we investigated rSO_2 during CPB.

Perfusion 1996; **11**: 241–245

Surface coating of cardiopulmonary bypass circuits

Ludwig K von Segesser Clinic for Cardiovascular Surgery, University Hospital, Chuv, Lausanne

Hence, there is now ample evidence that surface modification allows for significant improvement of the biocompatibility of artificial surfaces. In order to develop even better devices, it is necessary to develop further, not only surface modification, but also the design of the devices taking into account the improvement of fluidics as well as the requirements of the modified artificial surfaces.

METHYLPREDNISOLONE REDUCES THE INFLAMMATORY RESPONSE TO CARDIOPULMONARY BYPASS IN NEONATAL PIGLETS: TIMING OF DOSE IS IMPORTANT

Andrew J. Lodge, MD
Paul J. Chai, MD
C. William Daggett, MD
Ross M. Ungerleider, MD
James Jaggers, MD

(J Thorac Cardiovasc Surg 1999;117:515-22)

In summary, the administration of high-dose methylprednisolone 8 hours and immediately before operations involving CPB in infants offers a relatively inexpensive and readily available means of protection from the inflammatory response to CPB compared with no treatment. Furthermore, the use of this dosing strategy is superior to one in which methylprednisolone is administered at or around the time of the inflammatory stimulus of CPB. The use of this strategy may substantially reduce morbidity after CPB and hospital costs, especially if used in selected high-risk patients.

CARDIOPULMONARY BYPASS, MYOCARDIAL MANAGEMENT, AND SUPPORT TECHNIQUES

HIGHER HEMATOCRIT IMPROVES CEREBRAL OUTCOME AFTER DEEP HYPOTHERMIC CIRCULATORY ARREST

Toshiharu Shin'oka, MD[a]
Dominique Shum-Tim, MD, MSc[a]
Richard A. Jonas, MD[a]
Hart G. W. Lidov, MD, PhD[b]
Peter C. Laussen, MB, BS[c]
Takuya Miura, MD[a]
Adre du Plessis, MD[d]

Conclusion: **Extreme hemodilution during cardiopulmonary bypass may cause inadequate oxygen delivery during early cooling. The higher hematocrit with a blood prime is associated with improved cerebral recovery after deep hypothermic circulatory arrest. (J Thorac Cardiovasc Surg 1996;112:1610-21)**

PERIOPERATIVE EFFECTS OF ALPHA-STAT VERSUS pH-STAT STRATEGIES FOR DEEP HYPOTHERMIC CARDIOPULMONARY BYPASS IN INFANTS

Adre J. du Plessis, MBChB, MPH
Richard A. Jonas, MD
David Wypij, PhD
Paul R. Hickey, MD
James Riviello, MD
David L. Wessel, MD
Stephen J. Roth, MD, MPH
Frederick A. Burrows, MD
Gene Walter, REEGT
David M. Farrell, MA, CCP
Amy Z. Walsh, RN
Christine A. Plumb, RN, MSN
Pedro del Nido, MD
Redmond P. Burke, MD
Aldo R. Castaneda, MD
John E. Mayer, Jr., MD
Jane W. Newburger, MD, MPH

(J Thorac Cardiovasc Surg 1997;114:991-1001)

In conclusion, these data contradict the widely held notion that alpha-stat management is more physiologic and protective during hypothermic cardiopulmonary bypass in infants. Indeed, the current study suggests that the pH-stat management may enhance systemic and cerebral protection during repair of congenital heart lesions in infants in whom deep hypothermic cardiopulmonary bypass is used with or without circulatory arrest. However, management with the pH-stat strategy may be more complex and may require a period of training for perfusionists who are unfamiliar with this technique. Delineation of the longer-term effects of these pH management strategies awaits follow-up of this population.

Intermittent Perfusion Protects the Brain During Deep Hypothermic Circulatory Arrest

Stephen M. Langley, FRCS, Paul J. Chai, MD, Sara E. Miller, PhD, James R. Mault, MD, James J. Jaggers, MD, Steven S. Tsui, MD, Andrew J. Lodge, MD, Ann Lefurgey, PhD, and Ross M. Ungerleider, MD

Department of Surgery, Duke University Medical Center, Durham, North Carolina

(Ann Thorac Surg 1999;68:4–13)

Conclusions. Intermittent perfusion during DHCA is clinically practical and results in normal cerebral metabolic and ultrastructural recovery. Furthermore, the correlation between brain structure and $CMRO_2$ suggests that monitoring $CMRO_2$ during the operation may be an outstanding way to investigate new strategies for neuroprotection designed to reduce cerebral damage in children undergoing correction of congenital cardiac defects.

REGIONAL LOW-FLOW PERFUSION PROVIDES CEREBRAL CIRCULATORY SUPPORT DURING NEONATAL AORTIC ARCH RECONSTRUCTION

Frank A. Pigula, Edwin M. Nemoto, Bartley P. Griffith and Ralph D. Siewers

J Thorac Cardiovasc Surg 2000;119:331-339

The reduction of deep hypothermia and circulatory arrest time required may reduce the risk of cognitive and psychomotor deficits. (J Thorac Cardiovasc Surg 2000;119:331-9)

Neurologic outcomes in children with post-pump choreoathetosis

Kenton R. Holden, MD, Jessica C. Sessions, MD, Joel Curé, MD, David S. Whitcomb, MD, and Robert M. Sade, MD

THE JOURNAL OF PEDIATRICS
Volume 132, Number 1 1998;132:162-4

In conclusion, cyanotic heart disease predicts the development of basal ganglia lesions and is also associated with persistence of PPC. Most patients with persistent PPC had a significant decrease in their DQ compared with their preoperative condition. In the patient who has PPC develop after CPB, preoperative cyanosis and the development of a basal ganglia lesion suggests a worse prognosis. In addition, the presence of TCA is associated with a decrease in DQ but not persistence of choreoathetosis.

Reporting and preventing medical mishaps: lessons from non-medical near miss reporting systems

Paul Barach, Stephen D Small

BMJ VOLUME 320 18 MARCH 2000

Conclusions

Non-punitive, protected, voluntary incident reporting systems in high risk non-medical domains have grown to produce large amounts of essential process information unobtainable by other means. Non-medical incident reporting systems have evolved over the past three decades to emphasise near misses, in addition to adverse events, to encourage confidentiality over anonymity, and to move beyond traditional linear thinking about human error, to analyses of multiple causation at the level of systems.

Results

JECT. 2012;44:216–223
The Journal of ExtraCorporeal Technology

Improvements in Survival and Neurodevelopmental Outcomes in Surgical Treatment of Hypoplastic Left Heart Syndrome: A Meta-Analytic Review

Joseph J. Sistino, PhD, CCP; Heather Shaw Bonilha, PhD

College of Health Professions, Medical University of South Carolina, Charleston, South Carolina

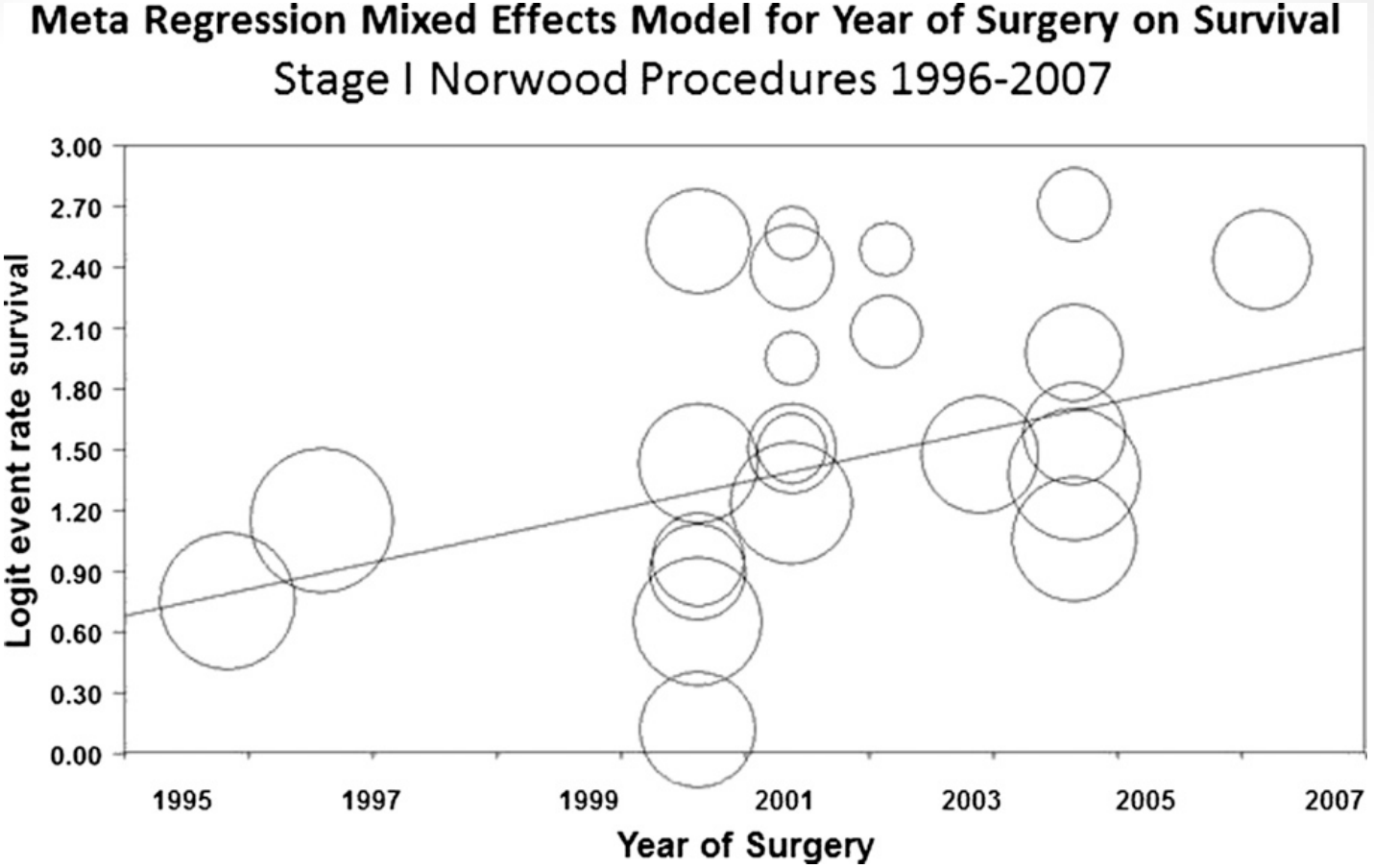


Figure 2. Hospital survival following Stage I Norwood significantly increased from 1996–2007 ($p < .05$) (15 studies). Circle sizes are proportional to the study sample sizes.

Improvements in Survival and Neurodevelopmental Outcomes in Surgical Treatment of Hypoplastic Left Heart Syndrome: A Meta-Analytic Review. J. Sistino, H S Bonilha. JECT. 2012;44:216–223.

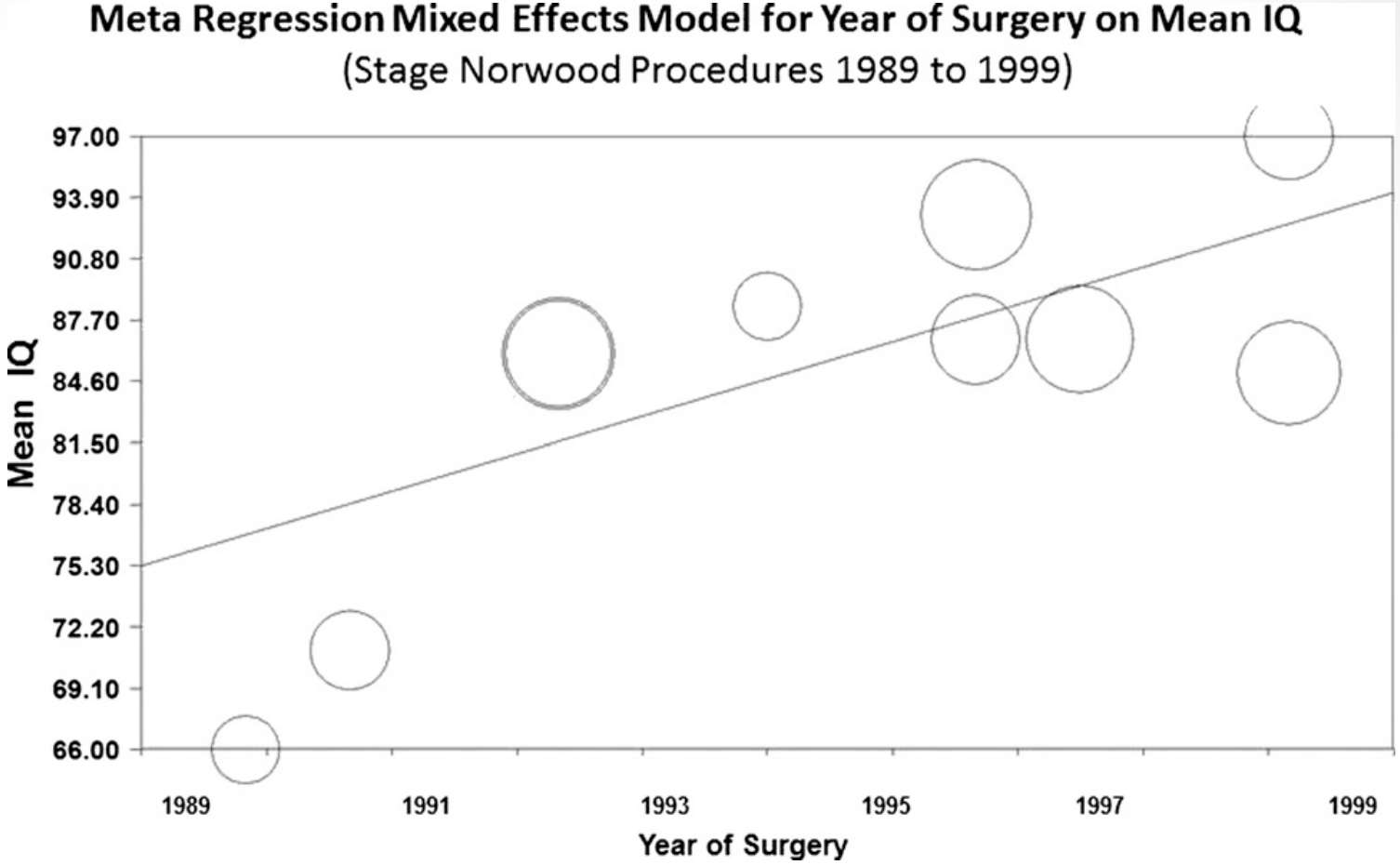
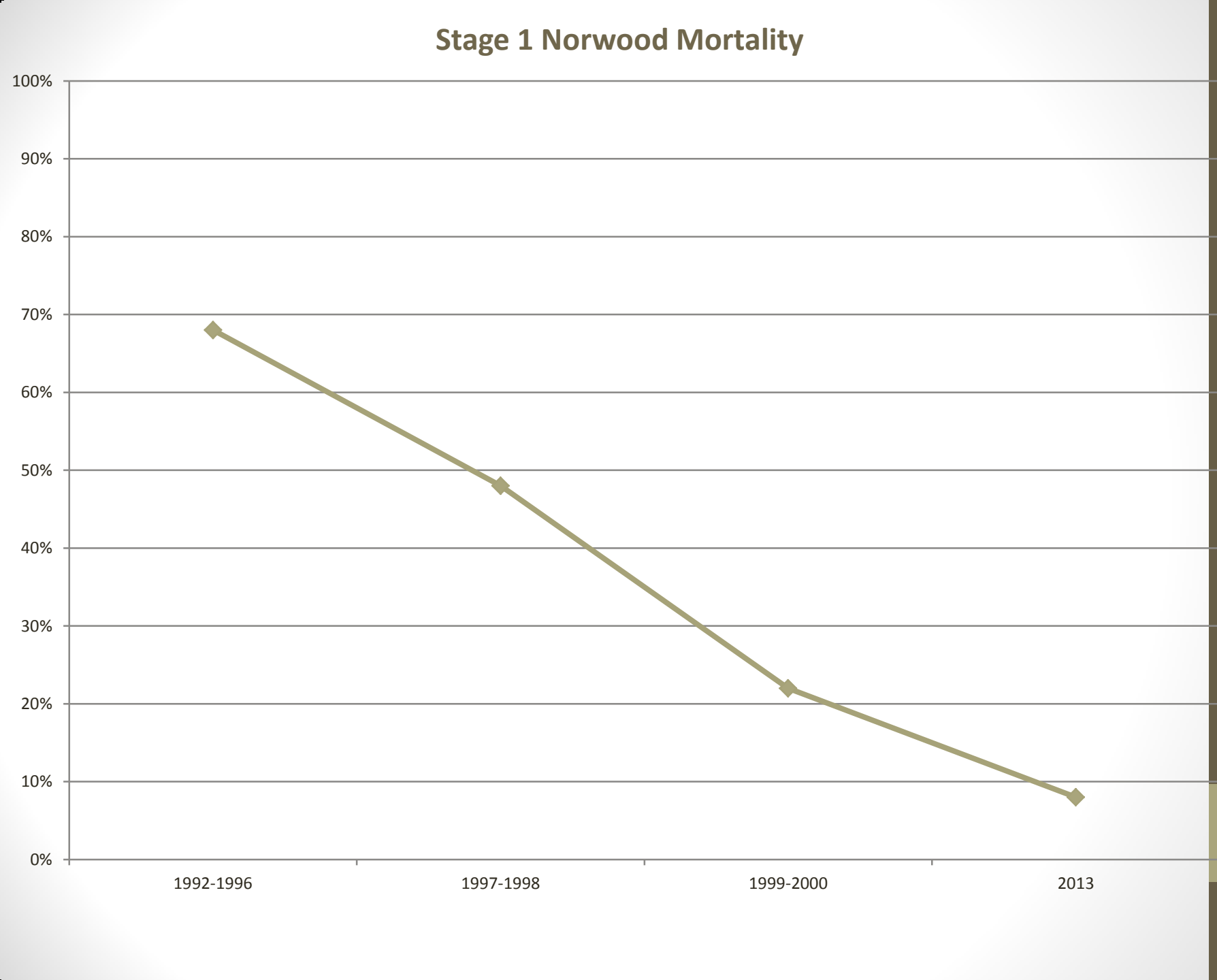
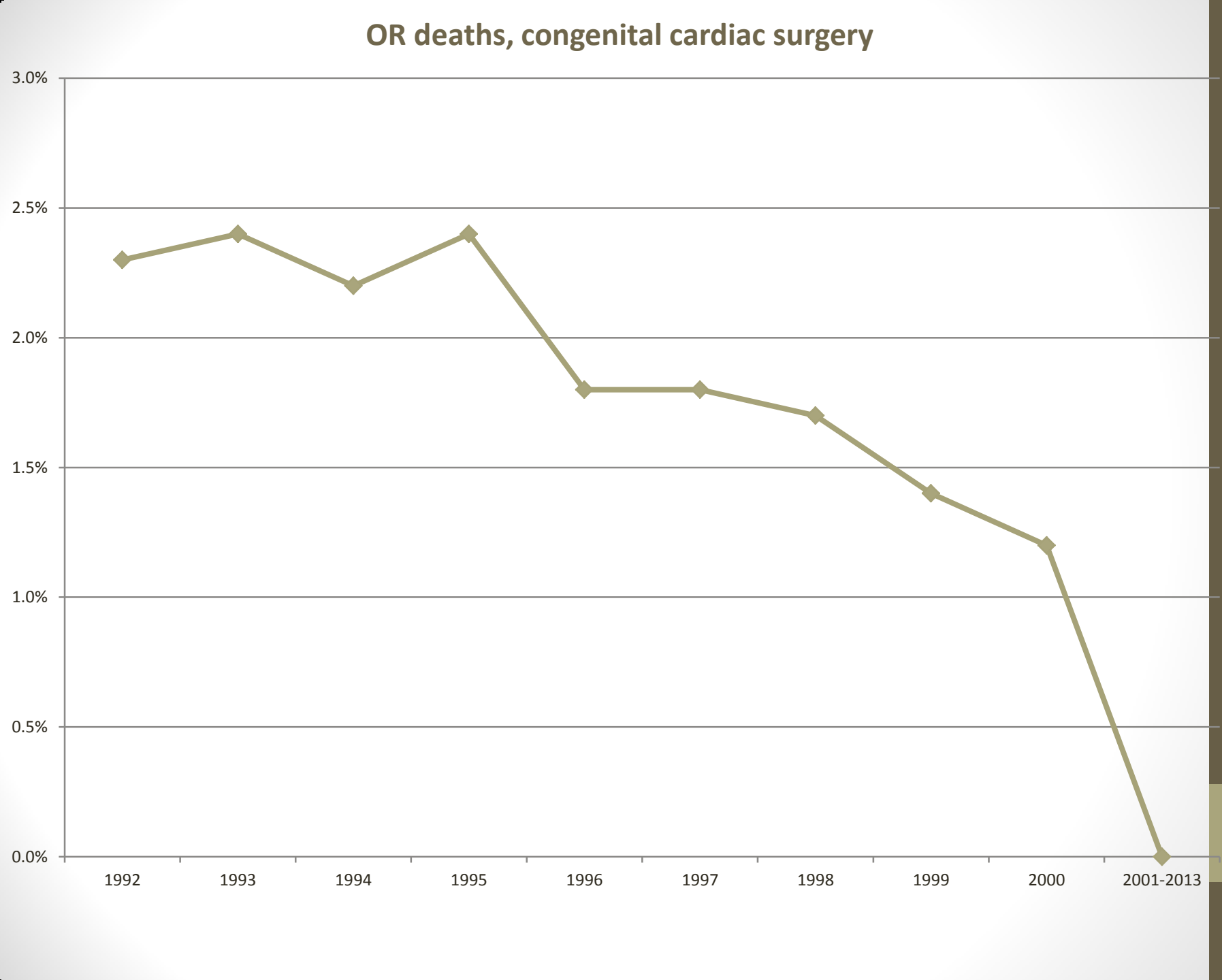
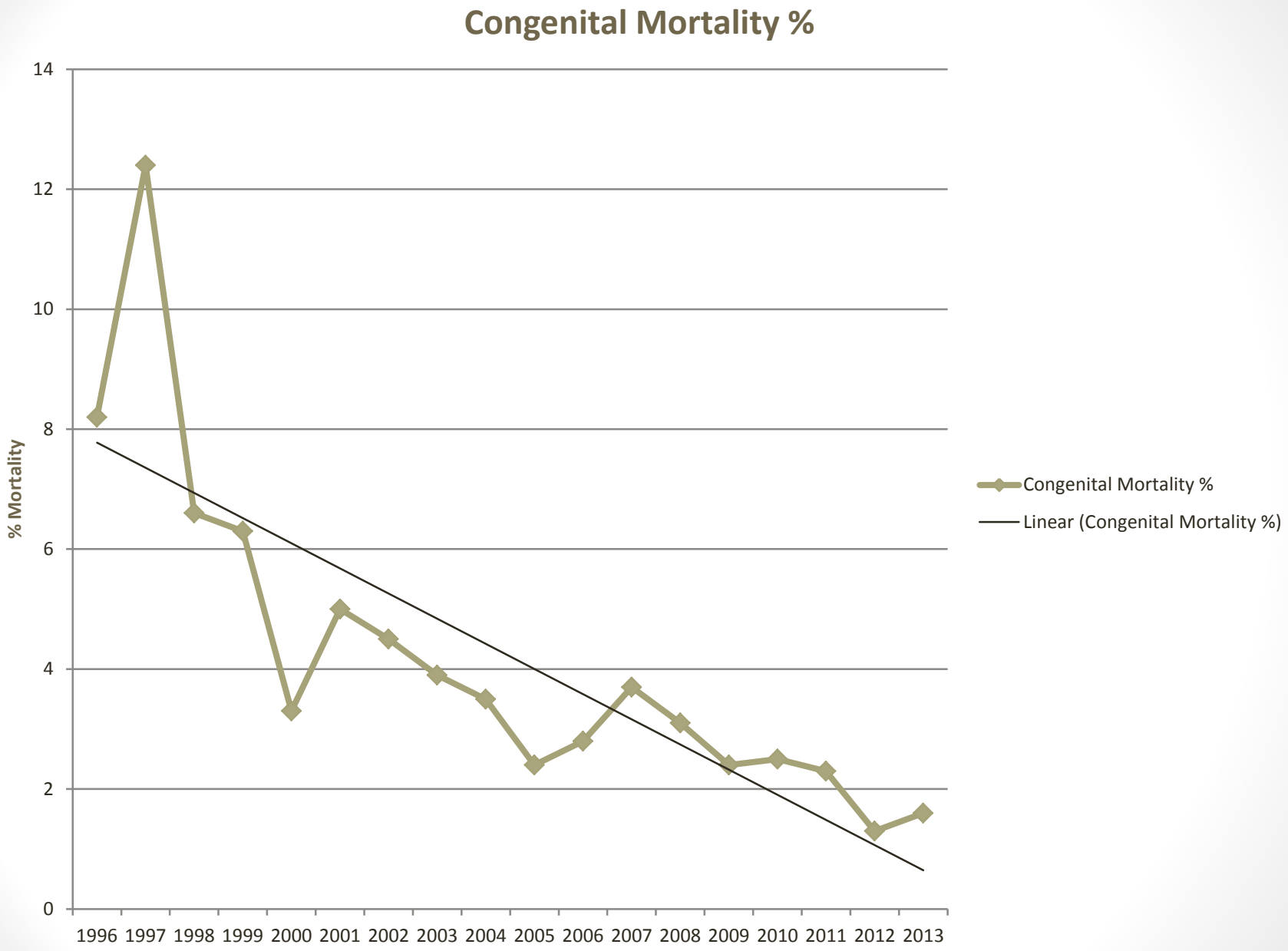


Figure 4. Mean IQ after Stage I Norwood significantly increased from 1989 to 1999 ($p < .05$). Circle sizes are proportional to the study sample sizes.

Improvements in Survival and Neurodevelopmental Outcomes in Surgical Treatment of Hypoplastic Left Heart Syndrome: A Meta-Analytic Review. J. Sistino, H S Bonilha. JECT. 2012;44:216–223.


Stage 1 Norwood Mortality
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1992-1996
1997-1998
1999-2000
2013


OR deaths, congenital cardiac surgery
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001-2013


Congenital Mortality %
% Mortality
14
12
10
8
6
4
2
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Congenital Mortality %
Linear (Congenital Mortality %)

Index Case Mortality for Children's Hospital Colorado

By Specific Operation	Heart Institute January 2009 – June 2013 Total Operations	Heart Institute Mortality %	STS Mortality %
Arterial Switch Repair	37	0	3.0%
AVSD Repair	81	0	2.7%
Fontan Procedure	57	0	1.7%
Norwood Procedure	63	7.9%	17.2%
TOF Repair	81	0	0.7%
VSD Repair	178	0	0.9%

1951 - 2013:

1951 - 1955

- 18 patients were reported to have had cardiac surgery with CPB at 6 different centers.
- There were 17 deaths and 1 survivor* (94.5% mortality)[1].
  - *May 1953, Gibbon

In the span of over 60 years pediatric cardiac surgery has gone from a mortality rate of 100% to mortality rates approaching 0% in many congenital heart conditions.

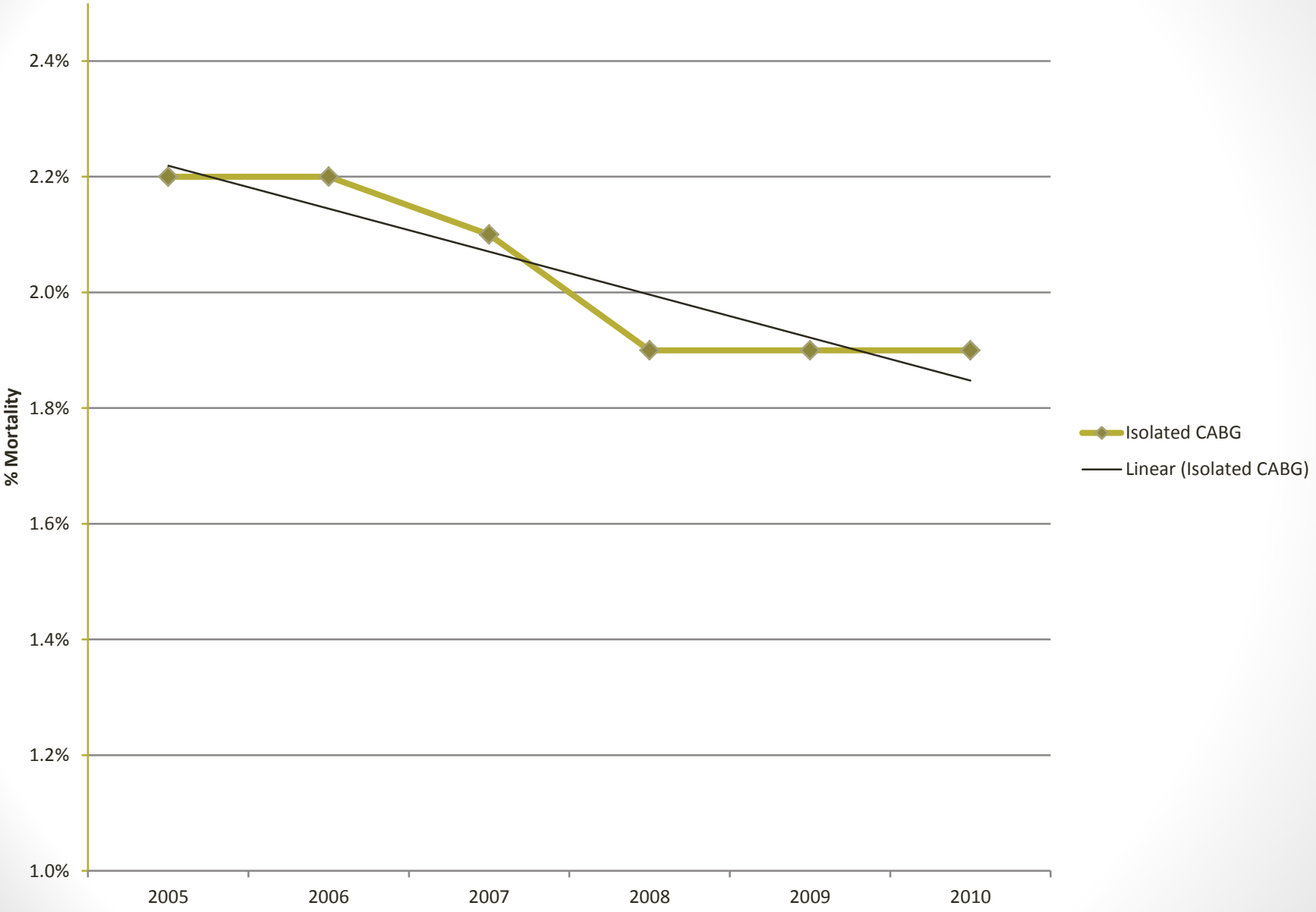
Major advances since 1980

in congenital cardiac surgery

- Transplantation
- Complete surgical repair vs. palliation in infancy
- Intraoperative ECHO
- Quality and safety initiatives
- Dedicated multidisciplinary care
  - Pediatric cardiologists
    - Imaging specialists
      - ECHO
      - MRI
    - Electrophysiologists
    - Transplant
    - Intervetionalists
  - Pediatric cardiac surgeons
  - Pediatric cardiac anesthesiologists
  - Pediatric cardiac intensivists
  - Pediatric perfusionists
    - Ultrafiltration techniques
    - Cooling and rewarming protocols
    - Miniaturization of circuits
    - Numerous cerebral protection strategies
    - Other…

Improvements in adult cardiac surgery

Isolated CABG



CONCLUSIONS

Over the past decade there have been significant reductions in the incidences of mortality, stroke, reoperations for bleeding, sternal wound infections, and new-onset renal failure in non-emergency patients. These outcomes seem to reflect improvements in the surgical procedure, rather than a change in the operative risk of patients currently undergoing CABG. Elective CABG is now performed in North America with a mortality rate of 1.6% and a stroke rate of 1.1%. Although these improvements in outcomes are significant, future challenges for cardiac surgery as a specialty are to focus on continued reduction of mortality of CABG, stroke, and renal failure. These outcomes should serve as benchmarks for competing therapies for multivessel cardiovascular disease.

El Bardissi AW, et al. Trends in isolated CABG: An analysis of the STS Adult cardiac surgery database. J Thorac Cardiovasc Surg 2012;143: 273-81.

California Cardiac Surgery and Intervention Project

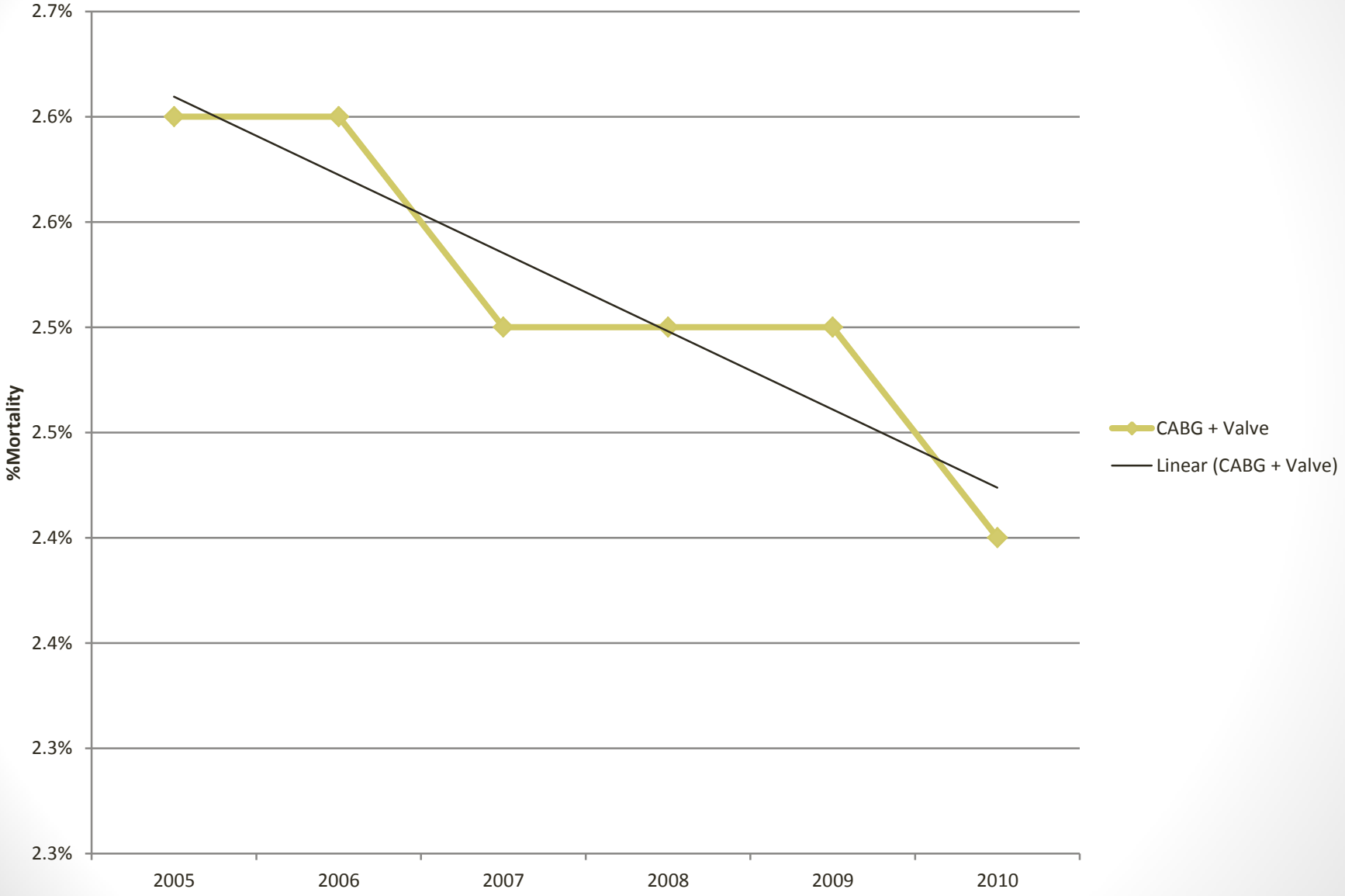
A comprehensive report on California hospitals performing heart surgery and percutaneous coronary intervention

Isolated AVR in-hospital mortality

California Cardiac Surgery and Intervention Project

A comprehensive report on California hospitals performing heart surgery and percutaneous coronary intervention

STS Nat'l. db
CABG + Valve



We build upon innovation

- What we now are able to achieve is directly linked to what those have done who have gone before us.

"We are like dwarfs sitting on the shoulders of giants. We see more, and things that are more distant, than they did, not because our sight is superior or because we are taller than they, but because they raise us up, and by their great stature add to ours.“

John of Salisbury, 12th century

In conclusion

- I think that Tom would be proud of how far we have come!

- But would strongly encourage us to keep building on the innovations that have come before us.

Thank You