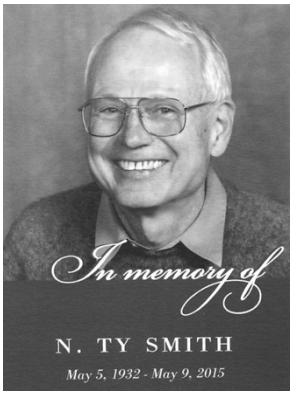
The Measures of a Man

2015 Ty Smith Lecture

Steven L. Shafer, M.D.
Professor of Anesthesiology, Perioperative and Pain Medicine, Stanford University
Adjunct Professor of Biopharmaceutical Sciences, UCSF
Editor-in-Chief, Anesthesia & Analgesia



In Memory of N. Ty Smith
May 5, 1932 - May 9, 2015

Ty's contributions to anesthesia were numerous. In addition to his organizing role in STA and founding of the Journal of Clinical Monitoring, Ty made major contributions in the fields of closed loop control of anesthesia, modeling, simulation, narcotic-induced rigidity - all at the same time.

Those of us who worked with Ty knew to bring something to read while waiting for him, but he would take the time to steer you in the right direction. Ty foresaw the use of immersive simulation in anesthesia, brought the first computer into an OR, and championed improvements in intraoperative monitoring.

An avid photographer, he would come back from trips with 10 rolls of Kodachrome. Long before PowerPoint, Ty could give a 50 minute talk with two carousels on two screens and keep everything in sync. Ty also found time for opera, orchids, and family.

We are all saddened by the passing of this great visionary, but rededicate our efforts to keep his memory alive through the Society.

Mr. N. Ty Smith M.D., Ph.D. is a Professor of Anaesthesiology at UCSD, San Diego, CA, USA. Mr. Smith served for two years in the Navy and spent nine years on the faculty of Stanford University and twenty-four at the University of California, San Diego.

During the 45 years of his professional life, he spent much of his time with a computer.

His work has included cardiovascular physiology and pharmacology, EEG analysis and display, closed-loop control, drug interactions, physiologic and pharmacologic mathematical modeling, simulation, noninvasive monitoring, the human pharmacology of inhaled anesthetic agents, and automated record keeping, including voice recognition.

Mr. Smith was a Founding Editor of the Journal of Clinical Monitoring, the Founding President of the Society for Technology in Anesthesia, and has served on and helped put together many meetings. Mr. Smith serves as a Member of the Scientific Board of BMEYE B.V. He serves as Member of Corporate Advisory Board at Virtual Heroes, Inc. As founding Chair of the American Society of Anesthesiologists Committee on Electronic Media and Information Technology, he helped hold the ASA into the electronic world.

His current work includes mathematical modeling and simulation of physiology and pharmacology. During his prolific career, he has authored over 400 publications.

S Afr Dent J. 1946 Apr;20:97

Dental disease as a fundamental problem.

Smith NT

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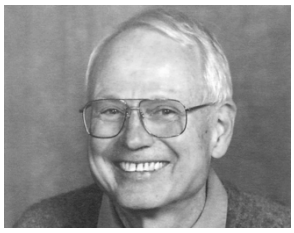


J Appl Physiol. 1962 Mar;17:306-10

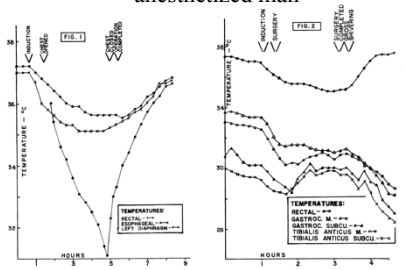
Subcutaneous, muscle, and body temperatures in anesthetized man

N. Ty Smith
Anesthesia Laboratories, Massachusetts General Hospital, Boston, Massachusetts

Temperatures were recorded continually in 39 patients. Preinduction temperatures were, in decreasing order, ($P < .01$) 1) rectum and esophagus, 2) intercostal muscle, 3) gastrocnemius muscle and intercostal subcutaneous, 4) tibialis anticus muscle, and 5) tibialis anticus and gastrocnemius subcutaneous.

J Appl Physiol. 1962 Mar;17:306-10

Subcutaneous, muscle, and body temperatures in anesthetized man



35 y.o. man 7 y.o. girl

J Appl Physiol. 1962 Mar;17:306-10

Subcutaneous, muscle, and body temperatures in anesthetized man

Region	Initial Temp., C[a]			Temp. Changes During Preduction Per., C[b]		Temp. Decrease During Anesthesia, C[c]			Temp. Rise Before End of Surgery, C[d]		Temp. Changes During Recovery Per., C[e]			Final Temp., C[f]	
	No.	Mean	SD	Mean	SD	No.	Mean	SD	Mean	SD	No.	Mean	SD	Mean	SD
Rectum	39	37.16	0.38	−0.04	0.64	32	0.99	0.72	0.24	0.31	32	0.64	0.62	36.87	0.67
Esophagus	27	36.94	0.45	−0.05	0.53	27	1.05	0.68	0.20	0.18	27	0.57	0.21	36.76	0.44
Subcutaneous															
Gastrocnemius	28	32.31	1.45	0.24	1.10	21	1.96	1.75	0.96	1.17	21	−0.11	1.83	31.80	3.12
Tibialis anticus	26	32.34	1.66	−0.02	0.73	19	1.45	1.10	0.96	0.91	19	−0.61	2.22	32.29	3.25
Intercostal	22	34.94	1.13	0.25	0.74	22	2.20	1.32	0.52	0.67	22	0.72	1.13	34.26	1.49
Muscle															
Gastrocnemius	31	34.93	1.27	−0.17	0.63	24	1.49	1.73	0.47	0.66	24	0.02	0.88	34.26	2.29
Tibialis anticus	26	34.33	1.45	−0.24	0.93	19	1.59	1.17	0.49	0.75	19	0.20	0.57	33.68	2.95
Intercostal	22	36.65	0.50	0.01	0.32	22	1.23	0.66	0.36	0.31	22	0.61	0.19	36.36	0.73

JAMA. 1963 Mar 30;183:1078-81

Changes in Ventilation in Pediatric Patients After Removal of Gastric Contents

N. Ty Smith, MD, and Edwin J. Lilly, MD, Portsmouth, Va

Studies on 100 fasting infants and children anesthetized for elective surgery showed that there was often considerable gas and liquid in the stomach. The total volume of the gastric contents was sufficient to exert mechanical effects on respiratory movements… It is suggested that a gastric tube be passed in pediatric patients as soon as possible after induction of anesthesia, and the gastric contents removed.

JAMA. 1963 Mar 30;183:1078-81

Changes in Ventilation in Pediatric Patients After Removal of Gastric Contents

N. Ty Smith, MD, and Edwin J. Lilly, MD, Portsmouth, Va

Contents Removed

		Beginning of Anesthesia						
		Cc Air Removed			Cc Liquid Removed			
Age	No. of Studies	Mean	Range	SD	Mean	Range	SD
1-6 mo	6	31.7	9.5-73	23.5	1.6	0-2	0.9
6-12 mo	9	19.8	1-21	28.4	0.8	0-5	1.5
1-2½ yr	21	22.3	0-91.5	29.2	3.0	0-14	4.6
2½-5 yr	23	15.1	0-63	16.2	7.2	0-30	8.8
5-11 yr	36	22.9	0-129.5	25.9	8.3	0-44.5	11.1
Total	95	20.7	0-129.5	25.5	5.8	0-44.5	8.9

JAMA. 1963 Mar 30;183:1078-81

Changes in Ventilation in Pediatric Patients After Removal of Gastric Contents

N. Ty Smith, MD, and Edwin J. Lilly, MD, Portsmouth, Va

Changes in Ventilation

Age	No. of Studies	Mean V_T Before	SD	Mean V_T After	SD	Mean ΔV_T	SD	Mean % ΔV_T	SD
1-6 mo	7	24.4	6.0	29.5	5.7	5.1	3.0	21.1	16.5
6-12 mo	10	58.4	33.2	65.8	13.0	12.4	15.7	23.2	16.2
1-2½ yr	26	58.1	47.0	65.1	51.9	12.0	4.1	22.5	33.9
2½-5 yr	28	58.6	46.7	73.5	44.9	14.9	15.5	25.3	19.4
5-11 yr	46	126.4	66.6	140.0	65.5	13.6	15.4	10.8	21.3
Total	117*	81.6	64.9	94.5	64.8	12.9	13.7	18.5	23.8

Anesthesiology. 1965 Sep-Oct;26:633-41

The Hemodynamic Effects of Potassium Infusion in Dogs

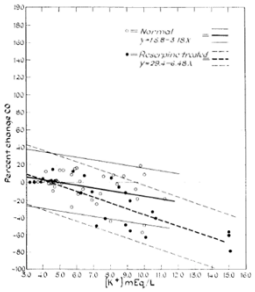
N. Ty Smith, M.D., and Aldo N. Corbascio, M.D.

The hemodynamic effects of K infusion were studied in 8 normal and 5 reserpine-treated dogs. Arterial blood K levels were correlated with changes in hemodynamic parameters.

Normal animals were more resistant to deleterious changes in cardiac output, total peripheral resistance, mean transit time, heart rate, mean arterial pressure, stroke volume, and left ventricular work, although the difference was statistically significant only with the first three parameters.

Anesthesiology. 1965 Sep-Oct;26:633-41

The Hemodynamic Effects of Potassium Infusion in Dogs



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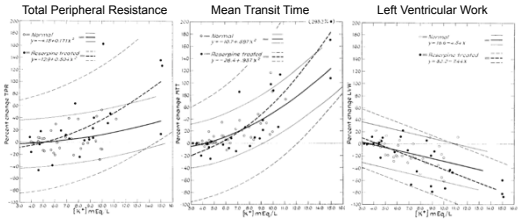

ANESTHESIA and ANALGESIA ... Current Researches VOL. 45, No. 5, SEPTEMBER-OCTOBER, 1966

INTERACTION BETWEEN PENTOBARBITAL AND DECREASED CALCIUM ION ON GUINEA PIG ATRIA

N. Ty Smith, M.D., and Aldo N. Corbascio, M.D.

BOTH ANESTHETIC agents and decreased calcium ion depress the myocardium. A similarity of action between the two factors suggests that they may significantly interact with each other on the myocardium. This interaction may influence the circulatory depression noted during massive transfusions in anesthetized patients. As an initial approach to the problem, the interaction of pentobarbital and decreased calcium ion was studied on the isolated guinea pig atrium

ANESTHESIA and ANALGESIA ... Current Researches VOL. 45, No. 5, SEPTEMBER-OCTOBER, 1966

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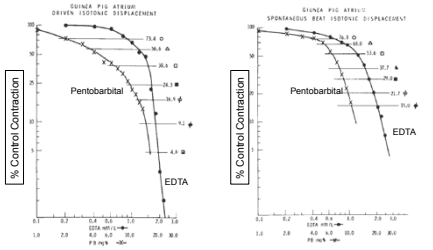
ABOUT THE AUTHORS

Dr. Smith

★ N. Ty Smith, M.D. is Assistant Professor of Anesthesia at Stanford Medical School in Palo Alto, California. He received his M.D. degree from Harvard Medical School, Boston, Massachusetts, in 1957. He interned at Children's Medical Center in Boston, 1957-1958, and took a residency at Massachusetts General Hospital in Boston, 1958-1960.

★ Aldo N. Corbascio, M.D. is Associate Research Pharmacologist at the University of California Medical School in San Francisco. A native of Italy, he received his M.D. degree from the University of Bari in 1953. He served a rotating internship from 1954-1955 at the Hospital of the University of Bari. Dr. Corbascio was a Fulbright Scholar at the University of Pennsylvania (Philadelphia), 1955-1956, and a Fellow in Cardiovascular Disease, 1956-1957.

INTERACTION BETWEEN PENTOBARBITAL AND DECREASED CALCIUM ION ON GUINEA PIG ATRIA



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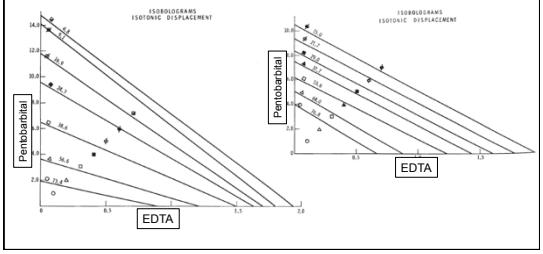


ANESTHESIA and ANALGESIA ... Current Researches VOL. 45, No. 5, SEPTEMBER-OCTOBER, 1966

INTERACTION BETWEEN PENTOBARBITAL AND DECREASED CALCIUM ION ON GUINEA PIG ATRIA

N. Ty Smith, M.D., and Aldo N. Corbascio, M.D.

The professional man has no right to be other than a continuous student. - *G. V. Black*

* * *

There never was a good war or a bad peace. - *Benjamin Franklin*

* * *

We may be personally defeated, but our principles, never!- *William Lloyd Garrison*

* * *

Greatness is only one of the sensations of littleness. - *John Tanner*

Anesthesiology. 1966 Sep-Oct;27(5):560-6

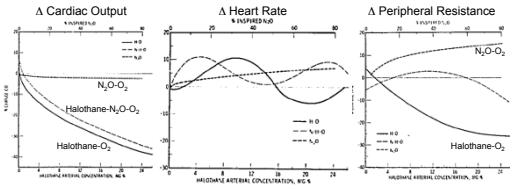
The Cardiovascular Effects of Nitrous Oxide During Halothane Anesthesia in the Dog

N. Ty Smith, M.D., and Aldo N. Corbascio, M.D.

Nitrous oxide-oxygen, halothane-oxygen, and nitrous oxide-oxygen-halothane were administered in random order to each of 12 dogs. Thirteen cardiovascular parameters-cardiac output, stroke volume, heart rate, mean arterial pressure, systolic arterial pressure, total peripheral resistance, mean transit time, left ventricular pressure, right ventricular pressure, the time derivatives of the pressures, and the left ventricular ejection time were plotted against concentrations of nitrous oxide and halothane.

Anesthesiology. 1966 Sep-Oct;27(5):560-6

The Cardiovascular Effects of Nitrous Oxide During Halothane Anesthesia in the Dog



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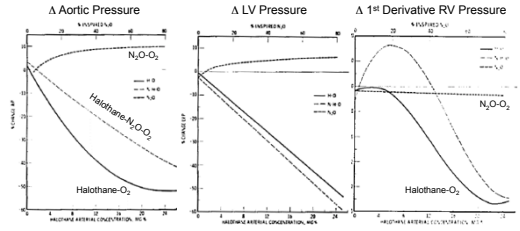


Anesthesiology. 1966 Sep-Oct;27(5):560-6

The Cardiovascular Effects of Nitrous Oxide During Halothane Anesthesia in the Dog

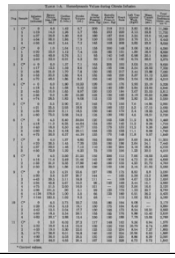
N. Ty Smith, M.D., and Aldo N. Corbascio, M.D.

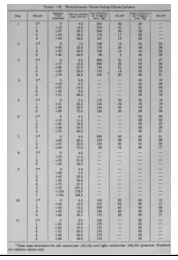
Since considerably greater analgesia was achieved when nitrous oxide was added to a given concentration of halothanc, nitrous oxide used with halothane spares the cardiovascular system, in a relative way.

Anesthesiology. 1967 May-Jun;28(3):510-6

Hemodynamic Effects of Experimental Hypercitremia

Aldo N. Corbascio, M.D. and N. Ty Smith, M.D.



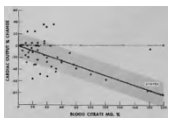


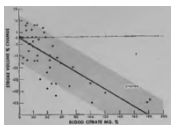
Anesthesiology. 1967 May-Jun;28(3):510-6

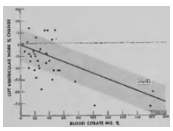
Hemodynamic Effects of Experimental Hypercitremia

Aldo N. Corbascio, M.D. and N. Ty Smith, M.D.

Cardiac Output | Stroke Volume | LV Work







Anesthesiology. 1967 May-Jun;28(3):510-6

Hemodynamic Effects of Experimental Hypercitremia

Aldo N. Corbascio, M.D. and N. Ty Smith, M.D.

"Clinical Workshop"

With this issue of the JOURNAL a new section heading appears: Clinical Workshop. The Editors have, for some time, felt that the former designations-Current Comment and Gadgets-did not do justice to the high caliber and importance of the material published under these headings.

LEROY D. VANDAM, M.D.
Editor-in-Chief

JAMA. 1967 Mar 6;199(10):704-8

Hemodynamic Effects of Gallamine and Tubocurarine Administered During Halothane Anesthesia

N. Ty Smith, MD and Charles E. Whitcher, MD

JAMA. 1967 Mar 6;199(10):704-8

Hemodynamic Effects of Gallamine and Tubocurarine Administered During Halothane Anesthesia

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Anesthesiology. 1967 Jul-Aug;28(4):735-48

Acute Hemodynamic Effects of Methoxamine in Man

N. Ty Smith, MD and Charles E. Whitcher, MD

JAMA. 1967 Mar 6;199(10):704-8

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Anesthesiology. 1968 May-Jun;29(3):493-8

The Effects of Interaction Between Lidocaine and Pentobarbital on Toxicity in Mice and Guinea Pig Atria

N. Ty Smith, MD and Charles E. Whitcher, MD

Br J Pharmacol Chemother. 1967 Jun;30(2):240-50

Effect of propranolol on alpha-adrenergic blockade in the dog and isolated rabbit aortic strip

Olivares GJ, Smith NT, Aronow L

Arch Int Pharmacodyn Ther. 1967 Nov;170(1):108-16

Mode of action of hydralazine on guinea pig atria

Gershwin ME, Smith NT

Arch Int Pharmacodyn Ther. 1968 May;173(1):95-114

Hemodynamic effects of ouabain on the surgically denervated, autotransplanted dog heart

Smith NT, Gershwin ME, Hurley EJ

Arch Surg. 1969 Jan;98(1):44-8

Citrate infusion in dogs following cardiac autotransplantation. Studies on cardiovascular effects

Smith NT, Hurley EJ

Am J Physiol. 1969 Jan;216(1):46-9

Whole-body autoradiography of histamine-14-C in rats

Gershwin ME, Smith NT, Hood N

J Appl Physiol. 1969 Feb;26(2):241-7

Rapid computation of myocardial contractility in intact animals

Smith NT, Schwede HO

JAMA 1968;206:1495-1499

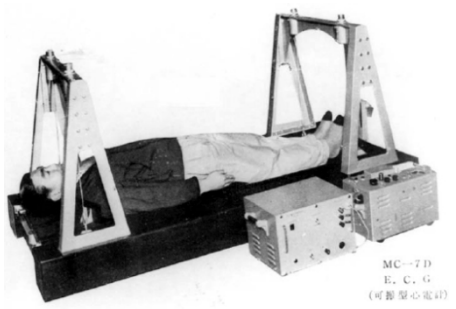
Cardiovascular Effects of Halothane in Man

N. Ty Smith, MD; Edmond I. Eger II, MD; Robert K. Stoelting, MD; and Charles E. Whitcher, MD

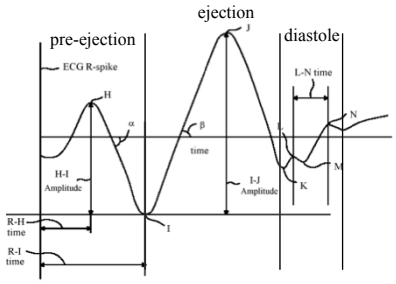
The cardiovascular response to induction of anesthesia with halothane-oxygen, as well as to changes in alveolar concentration from one steady-state level to another, was studied in eight subjects. Heart rate, arterial and right atrial pressures, stroke volume, cardiac output, left ventricular minute work, and total peripheral resistance were recorded beat-to-beat.

The last four variables were calculated by a ballistocardiograph - analogue computer system.

Ballistocardiograph



Ballistocardiogram



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KARGER 125 Medical and Scientific Publishers

1967 Monitoring of hemodynamic parameters by the BCG in conscious man.

1968 The BCG in cardiac homotransplantation.

1969 The relation between the ultra-low frequency ballistocardiogram, the 1969 acceleration pneumocardiogram, and ascending aortic flow acceleration in the 1969 baboon.

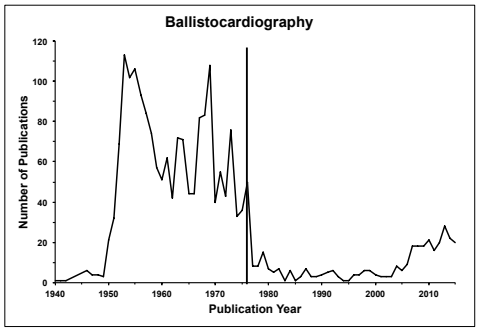
1971 ULF ballistocardiography in human cardiac transplantation.

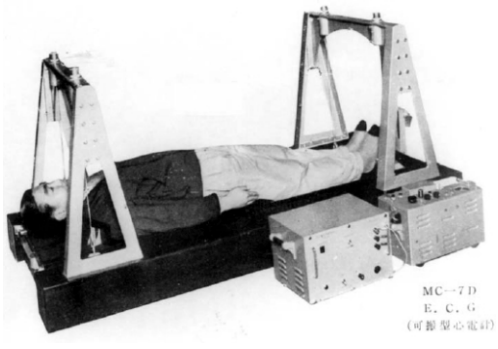
1971 The acceleration ballistocardiogram in relation to left ventricular flow in the **1976** baboon.

1973 The ultra-low-frequency ballistocardiogram in a young California gray whale.

1976 Opening address by the president of the American Ballistocardiographic Research **1976** Society.

1976 The BCG for measuring cardiac output in a California Gray Whale.





ANESTHESIA and ANALGESIA ... Current Researches VOL. 49, No. 5, SEPTEMBER-OCTOBER, 1970

The pneumocardiogram: a potential monitor for the operating room.

N. Ty Smith, M.D., and John A. Reitan, MD

The pneumocardiogram is familiar to all anesthesiologists as pulsations in the breathing bag, most readily apparent during apnea.

We tested the physiologic validity of the PNCG by comparing it with a standard index of cardiac function - peak ascending aortic blood acceleration (dQ/dtmax).

ANESTHESIA and ANALGESIA ... Current Researches VOL. 49, No. 5, SEPTEMBER-OCTOBER, 1970

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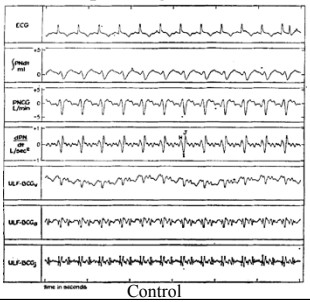

Control

ANESTHESIA and ANALGESIA ... Current Researches VOL. 49, No. 5, SEPTEMBER-OCTOBER, 1970

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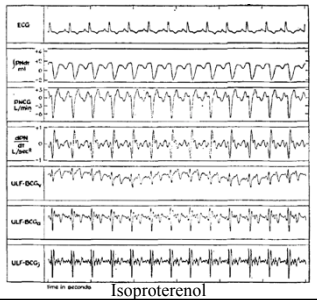

Isoproterenol

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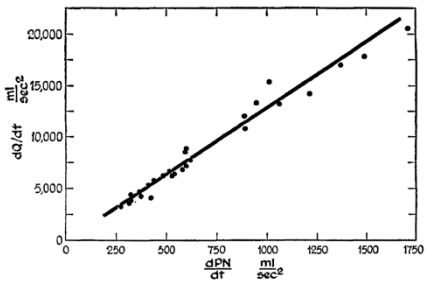


Br J Anaesth. 1970 Jan;42(1):87.

A non-invasive correlate of ascending aortic blood flow acceleration

John A. Reitan, N. Ty Smith And Leslie B. Kadis

The purpose of this study is to examine the relationship between blood flow acceleration and data useful for routine patient monitoring which is procured in a non-invasive and comfortable manner.

The variable investigated is the cardiac pre-ejection period (PEP), the interval during which energy is developed for ventricular ejection.

Br J Anaesth. 1970 Jan;42(1):87.

A non-invasive correlate of ascending aortic blood flow acceleration

John A. Reitan, N. Ty Smith And Leslie B. Kadis

Mongrel dogs with chronically implanted pulsed ultrasonic flow probes and arterial and venous catheters. Additional monitoring equipment included ECG leads and precordial and oesophageal microphones.

The pre-ejection period was calculated indirectly from the tracings of the ECG, phonocardiogram, and pulse wave form.

The calculation of the PEP and its squared reciprocal is readily performed with a small computer.

Anesthesiology. 1972 Jan;36(1):76-80..

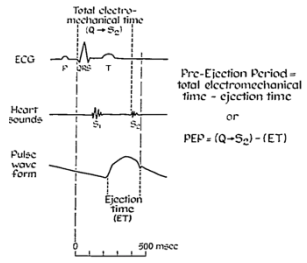
The cardiac pre-ejection period: a correlate of peak ascending aortic blood-flow acceleration

John A. Reitan, M.D., N. Ty Smith, M.D., V. Scott Borison, MS., Leslie B. Kadis, M.D.

The purpose of this study was to investigate the relationship between peak ascending aortic blood-flow acceleration and the cardiac pre-ejection period, on interval that can be obtained indirectly by noninvasive means.

Anesthesiology. 1972 Jan;36(1):76-80..

The cardiac pre-ejection period: a correlate of peak ascending aortic blood-flow acceleration



Anesthesiology. 1972 Jan;36(1):76-80..

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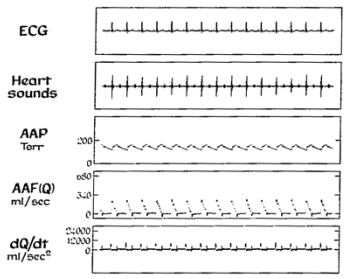

Anesthesiology. 1972 Jan;36(1):76-80..

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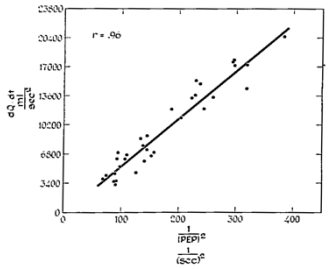


JAMA 1968;206:1495-1499

Cardiovascular Effects of Halothane in Man

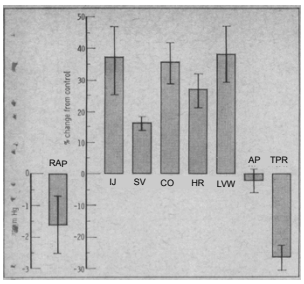
N. Ty Smith, MD; Edmond I. Eger II, MD; Robert K. Stoelting, MD; and Charles E. Whitcher, MD

The cardiovascular response to induction of anesthesia with halothane-oxygen, as well as to changes in alveolar concentration from one steady-state level to another, was studied in eight subjects. Heart rate, arterial and right atrial pressures, stroke volume, cardiac output, left ventricular minute work, and total peripheral resistance were recorded beat-to-beat.

The last four variables were calculated by a ballistocardiograph - analogue computer system.

JAMA. 1968 Nov 11;206(7):1495-9

Cardiovascular Effects of Halothane in Man



JAMA. 1968 Nov 11;206(7):1495-9

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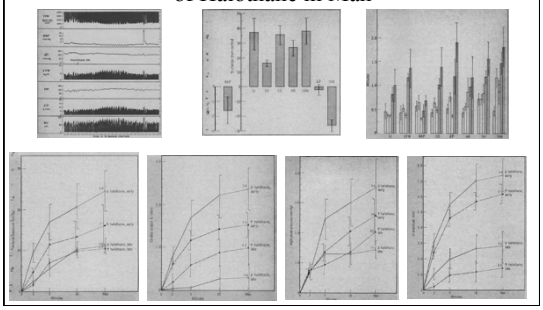


JAMA. 1968 Nov 11;206(7):1495-9

Cardiovascular Effects of Halothane in Man

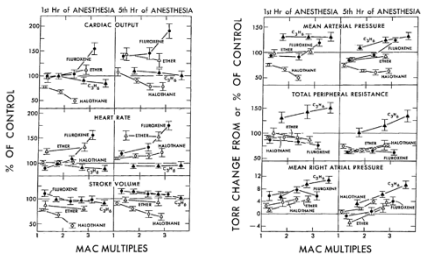
N. Ty Smith, MD; Edmond I. Eger II, MD; Robert K. Stoelting, MD; and Charles E. Whitcher, MD

The ballistocardiographic analogue computer technique used in this study allows us to examine induction of and rapid changes in anesthesia in a manner never before possible in humans. The advantages of this technique are many. We can study several parameters in a beat-to-beat fashion. Previously, the only possible way to do this was to perform a thoracotomy or to insert a rather long, large intra-arterial catheter. The Beg method is the only nondestructive method suitable for and proved in human subjects.

Anesthesiology. 1971 Jan;34(1):25-41

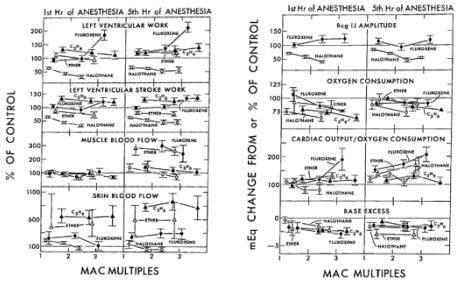
A comparison of the cardiovascular effects of halothane, fluroxene, ether and cyclopropane in man

Edmond I. Eger, II, M.D., N. Ty Smith, M.D., David J. Cullen, M.D., Bruce F. Cullen, M.D., George A. Gregory, M.D.



Anesthesiology. 1971 Jan;34(1):25-41

A comparison of the cardiovascular effects of halothane, fluroxene, ether, and cyclopropane in man



Anesthesiology 1970;32:218-30

Cardiovascular Effects of Fluroxene in Man

Bruce F. Cullen, M.D., Edmond I. Eger, II, M.D., N. Ty Smith, M.D., Donald C. Sawyer, D.V .M., Ph.D., George A. Gregory, M.D., Thomas A. Joas, M.D.

Anesthesiology 1970;32:396-409

Cardiovascular Effects of Halothane in Man

Edmond I. Eger, II, M.D., Norman Ty Smith, M.D., Robert K. Stoelting, M.D., David J. Cullen, M.D., Leslie B. Kadis, M.D., Charles E. Whitcher, M.D.

Anesthesiology 1970;32:410-21

The Cardiovascular and Sympathomimetic Responses to the Addition of Nitrous Oxide to Halothane in Man

Norman Ty Smith, M.D., Edmond I. Eger, II, M.D., Robert K. Stoelting, M.D. Thomas F. Whayne, M.D., David Cullen, M.D., Leslie B. Kadis, M.D.

Anesthesiology 1971;34:19-24

The Cardiovascular Effects of Diethyl Ether in Man

George A. Gregory, M.D., Edmond I. Eger, II, M.D., N. Ty Smith, M.D., Bruce F. Cullen, M.D., David J. Cullen, M.D.

Anesthesiology 1971;34:262-70

The effects of halothane anesthesia on reflex cardiovascular responses to simulated diving and the Valsalva maneuver

Thomas F. Whayne, Jr., M.D., N. Ty Smith, M.D., Edmond I. Eger, II, M.D., Robert K. Stoelting, M.D.,Charles E. Whitcher, M.D.

Anesthesiology 1971;35:32-37

The Effects of Ether, Halothane, and Forane on Apneic Thresholds in Man

Robert F. Hickey, M.D., Henry E. Fourcorle, M.D., Edmond I. Eger, II, M.D. C. Philip Larson, Jr., M.D., Steven H. Bohlman, M.D.,11 Wendell C. Stevens, M.D. George A. Gregory, M.D., Norman Ty Smith, M.D.

Anesthesiology 1971;34:415-20

The circulatory response to hypercapnia during fluroxene anesthesia in man

Bruce F. Cullen, M.D.; Edmond I. Eger, II, M.D., N. Ty Smith, M.D., Donald C. Sawyer, D.V.M., Ph.D., George A. Gregory, M.D.

Anesthesiology 1971;35:274-85

The cardiovascular effects of nitrous oxide-halothane anesthesia in man

S.H. Bahlman, M.D., E.I. Eger, II, M.D., N.T. Smith, M.D., W.C. Stevens, M.D., T. F. Shakespeare, M.D., D.C. Sawyer, Ph.D., M.J. Halsey, Ph.D., T.H. Cromwell, M.D.

Anesthesiology 1972;36:494-502

The cardiovascular effects of halothane in man during spontaneous ventilation.

S.H. Bahlman, M.D., E.I. Eger, II, M.D., M.J. Halsey, Ph.D., W.C. Stevens, M.D., T.F. Shakespeare, M.D., N.T. Smith, M.D.,T.H. Cromwell, M.D., H. Fourcade, M.D.

Anesth Analg. 1972;51:956-63

Cardiovascular effects of 40 percent nitrous oxide in man

John H Eisele, MD, N. N Ty Smith, MD

Can Anaesth Soc J. 1972;19:42-8

The cardiovascular responses to the addition of nitrous oxide to diethyl ether in man

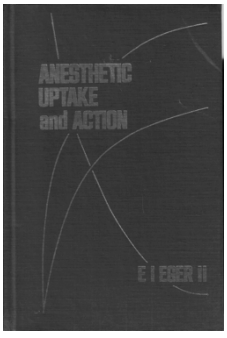
N. Ty Smith, M.D., Edmond I. Eger, II, M.D., George A. Gregory, M.D., Bruce F. Cullen, M.D., David J. Cullen, M.D.

Anesthesiology. 1974;40:301-4.

The cardiovascular effects of carbon dioxide in man awake and during diethyl ether anesthesia

George A. Gregory, M.D., Edmond I. Eger, II, M.D., N. Ty Smith, M.D., Bruce F. Cullen, M.D.

1974



J Biomech 1973;6:25-30

Regional myocardial dynamics from single-plane coronary cineangiograms.

Daughters GT, Ingels NB Jr, Carrera CJ, Wexler L, Smith NT.

Angiology 1972;23:500-8

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Acute haemodynamic effects of mephentermine in man.

Smith NT.

Eur J Pharmacol. 1970;9:289-96

Effect of temperature on toxicity and cardiac chronotropic action of sympathicotropic drugs.

Richards RK, Gershwin ME, Smith NT.

Proc Soc Exp Biol Med. 1969;131:82-4

The effects produced by the interaction between potassium ion and pentobarbital on the force of contraction of isolated guinea pig atria.

Smith NT, Gershwin ME.

Comput Biomed Res. 1972;5:228-38

Multiple model approach to uptake and distribution of halothane: the use of an analog computer

Aart Zwart, N. Ty Smith, Jan E. W. Beneken

Institute of Medical Physics, T.N.O. Department: Cardiovascular Physics, Utrecht, The Netherlands

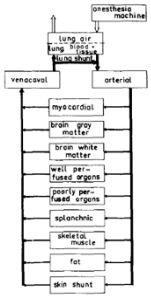
This paper describes a multiple analog computer model of the uptake and distribution of the anesthetic agent halothane.

The model consists of two interdependent loops, one representing the blood circulation and another representing the halothane transport.

Cardiac output and regional conductances are influenced in relation to the concentration of halothane in some relevant compartment of the model.

Comput Biomed Res. 1972;5:228-38

Multiple model approach to uptake and distribution of halothane: the use of an analog computer



$$p(t) = p_0(t),$$

$$\alpha(t) = \alpha(0) + \int_0^t \lambda_b q_b(t)[p_t(t) - p_b(t)]\,dt,$$

$$\alpha(t) = p(t)(\lambda_b V_b + \lambda_t V_t).$$

Equations (1)-(3) give

$$p(t) = p(0) + \frac{1}{\lambda_b V_b + \lambda_t V_t} \int_0^t \lambda_b\, q_b(t)[p_a(t) - p(t)]\,dt,$$

$$p(t) = p(0) + \frac{1}{\lambda_b V_b + \lambda_t V_t + V_e} \int_0^t \{\lambda_b q_b(t)[p_{vc}(t) - p(t)] + q_c(t)[p_a(t) - p(t)]\}\,dt,$$

$$p(t) = p(0) + \frac{1}{\lambda_b V_b + \lambda_t V_t} \int_0^t \lambda[\textstyle\sum g(t)p_t(t) - CO p(t)]\,dt$$

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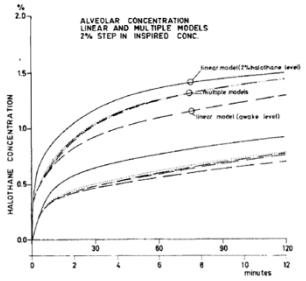
Multiple model approach to uptake and distribution of halothane: the use of an analog computer



Anesthesiology. 1972;37:47-58

Interaction between the circulatory effects and the uptake and distribution of halothane: use of a multiple model

Aart Zwart, N. Ty Smith, Jan E. W. Beneken

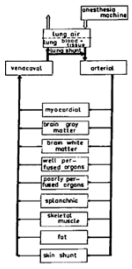


TABLE 2. Blood Volumes, Tissue Volumes, and Partition Coefficients for a 72-kg Man

Compartment	Blood Volume* (Liters)	Tissue Volume (Liters)	Partition Coefficient
Arterial	0.901	—	2.35
Brain			
Gray matter	0.371	0.75	5.4
White matter	0.199	0.75	8.3
Heart	0.145	0.30	5.1
Well-perfused organs (kidneys, adrenals, thyroid)	0.876	0.24	2.7
Poorly-perfused tissue (red marrow, nonfatty subcutaneous tissue)	0.117	6.2	53
Fat and fatty marrow	0.169	12.2	136
Splanchnic (organs drained by portal and hepatic circulations)	0.976	2.9	6.0
Skeletal muscle (muscle and skin nutritive)	0.449	35	8.1
Skin shunt	0.40	—	—
Vena cava	0.362	—	—
Lung	0.372	0.6	5.3

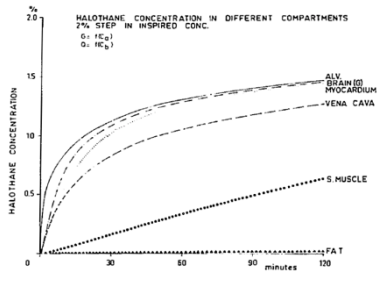
TABLE 3. Blood Flows in Man, Conscious and at 2 Per Cent Halothane

Compartment	Blood Flow, 2.5% Cardiac Index (L/min/sq m)	Blood Flow, 2.5% Cardiac Index (Liters/min)	Per Cent Change
Arterial	3.600	2.160	−40
Brain			
Gray matter	0.600	0.750	+25
White matter	0.150	0.188	+25
Heart	0.250	0.225	−10
Well-perfused organs	1.250	0.277	−78
(kidneys, adrenals, thyroid)			
Poorly-perfused tissue (red marrow, fatty subcutaneous tissue)	0.198	0.095	−50
Fat and fatty marrow	0.200	0.100	−50
Splanchnic (organs drained by portal and hepatic circulations)	1.450	0.715	−50
Skeletal muscle (muscle and skin nutritive)	1.200	0.460	−60
Skin shunt	0.500	0.750	+50
Vena cava	3.600	2.460	−40
Lung	5.676	3.376	−40

12 compartment analog computer model

Anesthesiology. 1972;37:47-58

Interaction between the circulatory effects and the uptake and distribution of halothane: use of a multiple model



Electroencephalogr Clin Neurophysiol. 1972;33:311-9

Spectral analysis of the EEG during halothane anaesthesia: input-output relations

F. H. Lopes da Silva, N. Ty Smith NT, A. A. Zwart, W.W. Nichols

Brain Research and Cardiovascular Physics Departments, Institute of Medical Physics TNO, National Health Research Organization, Utrecht (The Netherlands)
Department of Anesthesia, Stanford University Medical Center, Stanford, California

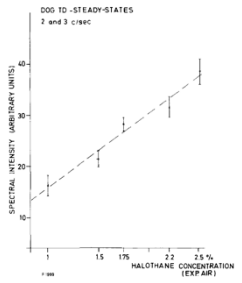
This study was performed to extract parameters from the EEG which would give quantitative information about brain function during Halothane anaesthesia.

The EEG was analysed by a hybrid spectral analyser, consisting of a bank of 20 electronic bandpass filters covering the frequency range 2-32 c/sec.

As a check on the analogue frequency analysis, a spectral analysis of some epochs was performed off-line on a digital computer (**PDP-9**) using the Fast Fourier Transform procedure.

Electroencephalogr Clin Neurophysiol. 1972;33:311-9

Spectral analysis of the EEG during halothane anaesthesia: input-output relations



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The effects produced by the interaction between potassium ion and pentobarbital on the force of contraction of isolated guinea pig atria.
Smith NT, Gershwin ME.

Anesthesiology. 1974;40:89-92

An equation system and programs for obtaining base excess using a programmable calculator

Gershwin R, Smith NT, Suwa KS

Acta Anaesthesiol Belg. 1976;27 suppl:327-41

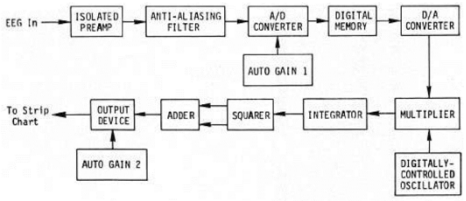
A computer module for the continuous monitoring of cardiac output in the operating theatre and the ICU.

Wesseling KH, Purschke R, Smith NT, Wüst HJ, de Wit B, Weber HA

Anesthesiology. 1979;50:456-60

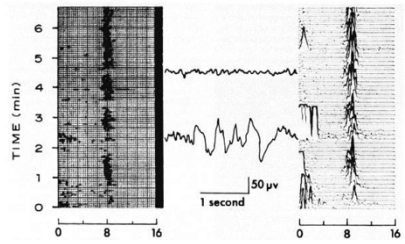
An inexpensive device for analyzing and monitoring the electroencephalogram

Robert A. Fleming, MS, and N. Ty Smith, MD



Anesthesiology. 1979;50:456-60

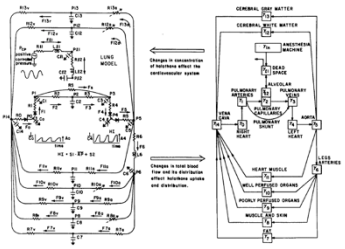
An inexpensive device for analyzing and monitoring the electroencephalogram



Anesthesiology. 1981;54:107-18

Interactions among ventilation, the circulation, and the uptake and distribution of halothane
Use of a hybrid computer multiple model: I. The basic model

Yasuhiro Fukui, and N. Ty Smith, MD



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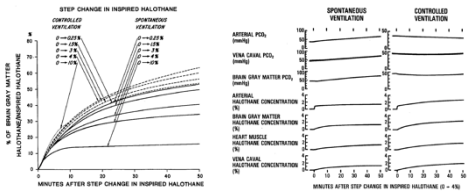
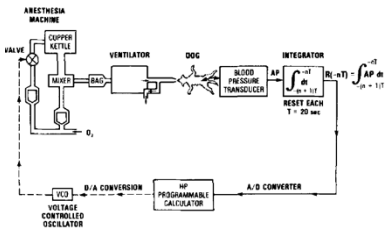


Anesth Analg. 1982;61:1010-5

Digital and sampled-data control of arterial blood pressure during halothane anesthesia

Yasuhiro Fukui, N. Ty Smith, MD, and Robert A. Fleming



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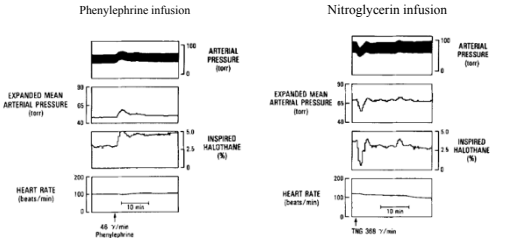
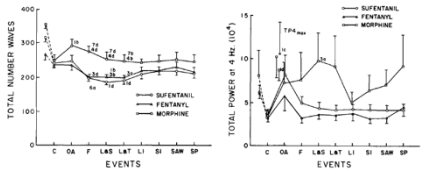


Anesth Analg. 1984;63:386-93

EEGs during high-dose fentanyl-, sufentanil-, or morphine-oxygen anesthesia

N. Ty Smith, MD, Holly Dec-Silver, RN, Ted J. Sanford JR, MD, Charles J. Westover JR, MD, Michael L. Quinn, PhB, Fritz Klein, PhD, and D. A. Davis, MD



Anesth Analg. 1984;63:715-22

Automatic control in anesthesia: a comparison in performance between the anesthetist and the machine

N. Ty Smith, MD, Michael L. Quinn, PhB, James Flick, Yasuhiro Fukui, PhD, Robert Fleming, and John R. Coles, PhD

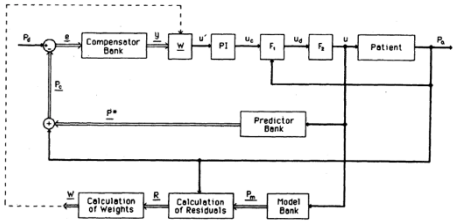
The scores for machine and anesthetists by system are shown in Tables 1-3. The scores combined from the three systems are shown in Table 4. In general, the machine's scores were considerably better than the anesthetists' scores. In addition, the machine's performance tended to be more consistent from experiment to experiment, as indicated by the larger coefficients of variation of the anesthetists' scores (not shown).

The machine scored better than the anesthetists in 38/42 possible scores, the differences in 19 scores being statistically significant. In no case was the anesthetists' score significantly better than the machine's.

IEEE Trans Biomed Eng. 1987;34:603-11

Multiple-model adaptive control of blood pressure using sodium nitroprusside

James F. Martin, Alan M. Schneider, N. Ty Smith



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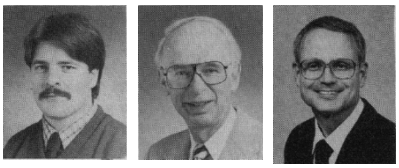
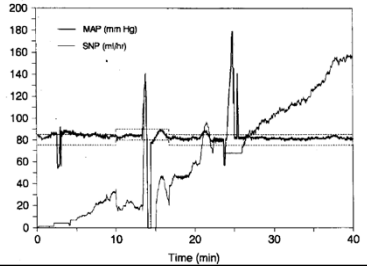


IEEE Trans Biomed Eng. 1992;39:389-93

Supervisory adaptive control of arterial pressure during cardiac surgery

James F. Martin, N. Ty Smith, Micheal L. Quinn and Alan M. Schneider

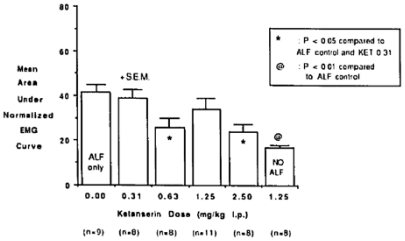
Patient in pain: SNP is replaces BP as vital sign



Anesthesiology. 1987;67:348-54

Ketanserin pretreatment reverses alfentanil-induced muscle rigidity

Matthew B. Weinger, M.D., Elizabeth J. Cline, B.S., N. Ty Smith, M.D., George F. Koob, Ph.D.



Stat Med. 1996 15;15:1199-215.

A measure of association for assessing prediction accuracy that is a generalization of non-parametric ROC area.

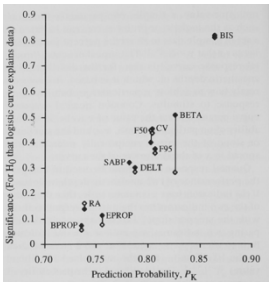
Warren D. Smith, Ph.D., Robert C. Dutton, M.D., N. Ty Smith, M.D.

$$P_K = \frac{\sum_{i=1}^{R-1} \sum_{i'>i} p_i p_{i'} P_{ii'}}{\sum_{i=1}^{R-1} \sum_{i'>i} p_i p_{i'}}$$

Anesthesiology. 1996;84:38-51

Measuring the performance of anesthetic depth indicators

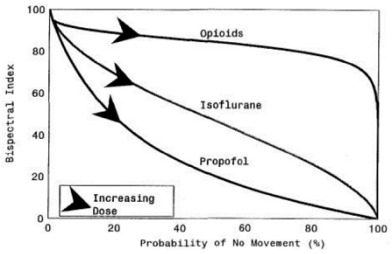
Warren D. Smith, Ph.D., Robert C. Dutton, M.D., N. Ty Smith, M.D.



Anesth Analg. 1997;84:891-9

A multicenter study of bispectral electroencephalogram analysis for monitoring anesthetic effect

Sebel PS, Lang E, Rampil IJ, White PF, Cork R, Jopling M, Smith NT, Glass PS, Manberg P



Anesth Analg. 1997;84:891-9

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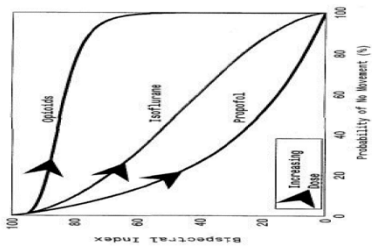
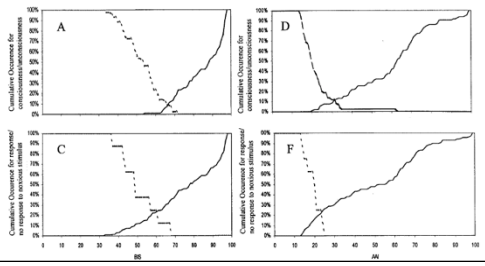


Anesthesiology. 2002;96:803-16

Performance of the ARX-derived Auditory Evoked Potential Index as an Indicator of Anesthetic Depth

Michel M. R. F. Struys, M.D., Ph.D., Erik Weber Jensen, Ph.D. Warren Smith, Ph.D., N. Ty Smith, M.D., Ira Rampil, M.S., M.D., Frank J. E. Dumortier, M.D., Christel Mestach, M.D., Eric P. Mortier, M.D., D.Sc.



Stud Health Technol Inform. 1998;50:309-15

Virtual medical trainer. Patient assessment and trauma care simulator

Kizakevich PN, McCartney ML, Nissman DB, Starko K, Smith NT

The Virtual Medical Trainer (VMET) combines multimedia sound and graphics with physiological engines, medical-procedures databases, and 3-D patients to produce an interactive environment that can mimic the cognitive pre-hospital assessment and care demands of a real emergency.

VMET uses a reconfigurable component software and training framework that allows a uniform user interface, ease of increasing training complexity, and expansion of the software components.

VMET provides an opportunity to experience a range of trauma scenarios prior to the challenge of an actual trauma situation

Current Opinion in Anaesthesiology 2000, 13:659±665

Simulation in anesthesia: the merits of large simulators versus small simulators

N. Ty Smith

I define `large' as the so-called realistic simulators, and `small' as everything else. Several words or phrases have been used to describe the large anesthesia simulators. These include high fidelity, realistic, theater and full scale.

I emphasize the merits of small simulators at the expense of large simulators.

Stud Health Technol Inform. 2005;111:488-91

The Physiology and Pharmacology of Growing Old, as Shown in Body Simulation

N. Ty Smith, Kenton R. Starko

We present a detailed model and simulation of the aging process.

To implement the aging process, we changed over 50 existing parameters that are part of a physiologic, pharmacologic multiple transport model of the human body.

To evaluate the new patients, we imposed three stresses: anesthesia induction, hemorrhage and apnea.

The elderly patients fared worse with anesthetic induction and with hemorrhage, but better with apnea.

Some independent data support our results.

Journal of Critical Care (2008) **23**, 157–166

Journal of Critical Care

The history of medical simulation

Kathleen R. Rosen MD

Department of Anesthesiology, Case Western Reserve University School of Medicine, Cleveland, OH 44106, USA

1928 Edwin Link builds first blue box trainer in basement of father's piano and organ factory.
1931 Link becomes full-time flight instructor. His school offers trainer and actual flight time.
1934 US Army buys 6 Link trainers.
1938 US Military purchases 10000 Link trainers. First plastic skeleton made by founders of Medical Plastics Laboratory.
1941 Rocket flight simulator completed.
1957 First successful external defibrillation with Johns Hopkins' equipment.
1958 Laerdal begins R&D for mouth-to-mouth mannequin. NASA develops biotelemetry.
1960 Resusci-Annie born. William Kouwenhoven introduces closed-chest massage.
1961 First primitive use of computer-assisted learning in medicine.
1963 Rescue vehicle equipped with coronary care equipment in Belfast, Ireland.
1964 GPE and NASA develop simulators for Gemini program. Howard Barrows introduces "Programmed Patient," providing first description of SPs in medical education.
1965 CA Gov Ronald Reagan authorizes paramedics to act as physician delegates. DC shock developed.
1967 First report of vfib resuscitation out of the hospital.
1968 AT&T designates 911 as national emergency telephone number. Cardiology Patient Simulator—"Harvey"—debuts from University of Miami.

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1970 Massachusetts General Hospital produces computerized clinical encounter simulations.
1972 NLM provides sponsorship and free access to medical simulations from Ohio State University, Massachusetts General Hospital, and University of Illinois.
1973 CPR introduced with instruction by the AHA and Red Cross. University of Wisconsin develops patient encounter simulation prototype as basis for future NBME computerized examinations.
1974 First AHA guidelines published with support from Laerdal.
1975 First description of Objective Structured Clinical Examination.
1978 Singer-Link pioneers computer imaging with introduction of DIG digital image generator. **N Ty Smith's group creates analog precursor to BodySim**.
1985 First PALS course offered. University of Michigan publishes first catalog of patient simulations. Effectiveness of computer simulations in medical practice demonstrated.
1986 CASE developed as standard precursor of CAELink simulator.
1988 CAE purchases Link simulation divisions from Singer. CAE-Link patient simulator

born in Palo Alto. Precursor to METI HPS born in Gainesville, FL.
1990 Anesthesia Simulator Consultant program released (pre-Anesoft anesthesia simulator).
1990 ECFMG pilots SP examination.
1992 Rhythm and Pulse released (pre-Anesoft ACLS simulator).
1993 First Medicine Meets Virtual Reality Conference. Rhythm and Pulse 2.0 update released.

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1994 ECFMG formally adopts SP assessment.
1994 NBME endorses SP examination to be implemented in 4 to 7 years.
1995 First University of Rochester Human Patient Simulation Conference. Wright's Anesthesia and Critical Care Resources on the Internet launches. Anesoft Corporation founded and releases Anesthesia Simulator 2.0, ACLS Simulator 3.0, and Critical Care Simulator.
1997 Sophus Medical develops acute care PC-based simulation. MIST-VR Trainer introduced.
1998 Anesoft Hemodynamic and Sedation Simulators introduced.
1999 Link facility in Binghamton closed. PediaSim created by METI. UMedic 4-year multimedia computer instruction system for cardiology introduced. Denx simulator for dentistry introduced.
2000 First International Meeting on Medical Simulation. Laerdal SimMan begins beta testing.
2001 METI releases Emergency Care Simulator. Sophus Medical partners with Laerdal.
2002 Medical Simulation Corporation's SimSuite opens first 2 centers: Swedish Heart Institute (Seattle, WA) and Geisinger Health System (Danville, PA). Anesoft Bioterrorism Simulator introduced.
2003 David Gaba receives the Society for Education in Anesthesia's Duke Prize for Excellence and Innovation in Anesthesia Education..

Journal of Critical Care (2008) 23, 157–166

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2.4. Software-based simulation

N Ty Smith and colleagues at the University of California–San Diego used their experience in cardiovascular physiology and anesthesia to develop Sleeper. It is based on sophisticated multicompartment modeling of physiology and pharmacology. It was the precursor of the current BodySim software. A fellow at the University of California–San Diego laboratory, Howard Schwid, simplified the models to run on a laptop and added critical event management. The Anesthesia Simulator Recorder became a commercial product in 1989. Later in the 1990s, a learning framework with objectives and feedback was added; and the software was renamed the Anesthesia Simulator Consultant (ASC). Further improvements in the ASC became the Anesthesia Simulator. The Sedation Simulator was created later (1998). Gas Man was also introduced in the 1990s. Its software displayed classic computer-based tutorials on anesthetic gas uptake and distribution.

From James Martin:

What I can tell you is that Ty Smith is responsible for my success.

I was starting my second year in Graduate school at UCSD pursuing a PhD in Orbital Mechanics (yes, I was heading down the path of being a rocket scientist). Ty came to my advisor looking for a control engineering expertise to a closed-loop drug delivery project he was working on. It was supposed to be a 3 month gig. Within those 3 months I was hooked on medicine / biomedical science.

I was in awe of Ty.

From James Martin:

I ended up switching my dissertation work from orbital mechanics to physiologic modeling and automated drug delivery. I spent 4 years working with Ty and got exposed to automated anesthesia record systems and simulation training. Both are now standard practice in anesthesia now, but in the early 80's they were new.

I learned all about the cardiovascular system and pharmacokinetics from Ty, and the anesthesia fellows he brought through (Matt Weinger, Jeff Mandel to name a couple). I got exposure to the conduct of animal studies, and even clinical studies while working for Ty. Everything I do today on Sedasys is rooted in what I learned working for Ty for those 4 years.

From James Martin:

Not once have I regretted my decision to leave orbital mechanics to become part of Ty's research program at UCSD.

From Howard Schwid:

Ty had an impact on my career years before I even met him. As a biomedical engineering student at the University of Wisconsin I studied the Smith-Fukui model of cardiovascular physiology and transport of halothane, developed during Ty's sabbatical in Madison, Wisconsin.

That model was years ahead of its time, built on the supercomputer of its day which combined analog and digital computing. The Smith-Fukui model included enough physiology and pharmacology to convince me that it should be possible build a computer model with sufficient fidelity to serve as the predictive engine for an anesthesia simulator with many drugs, a variety of patient conditions, and critical incidents.

From Howard Schwid:

Ty supported my fellowship position in 1985 and arranged for me to work with a flight simulator company interested in expanding into medical simulation. Together we built the first screen-based anesthesia simulator.

Looking back now it was amazing that Ty was able to make these connections and build the financial support for this project at a time when Apple was just releasing the first personal computer with a graphical user interface, before Microsoft Windows even existed. My year with Ty enabled me to start my career in academic anesthesiology with an emphasis on medical simulation. His support of my fellowship is just one example of his vision and leadership.

From Matt Weinger:

I have lots of impressions since I was one of his Fellows (1986-7) and then on faculty and a collaborator residing in an office nearby for 15 years. He was kind, gentle, and encouraging. He smiled a lot and seemed generally happy the vast majority of the time.

He was very supportive and I don't ever remember him losing his temper and saying anything negative to a menthe or colleague. He was brilliant and innovative. While Ty's focus was on computers and technology, he also was able to envision (or recognize) and then pursue interesting cross-disciplinary collaborations.

From Matt Weinger:

Shortly before I arrived for my fellowship, Ty had initiated a collaboration with George Koob at The Scripps Research Institute up the street from UCSD to study the mechanisms of opioid-induced muscle rigidity. Ty had observed muscle rigidity when doing clinical research with alfentanil for cardiac surgery and wondered why a neuronal depressant would cause an excitatory phenomenon. Further, some had reported that high dose opioids produced seizures but Ty thought it was just muscle rigidity.

When I arrived in San Diego (from UCSF), Howard Schwid was already in Ty's lab doing computer modeling of physiological processes (to create a simulator), which is what I had intended to do.

From Matt Weinger:

Ty suggested I work on opioid-induced rigidity. Since I had a Masters degree in neurobiology it turned out to be a good fit. Further, as I finished my fellowship and considered joining the faculty at UCSD, Ty convinced the VA to give me some lab space and then Janssen Pharmaceuticals into ponying up $40,000 as an unrestricted grant, equipping and staffing of my new lab.

Ty mentored me in the next couple of years to obtain a VA 'starter grant' and a Parker B Francis (ASA) Young Investigator Award to study the mechanisms of opioid-induced muscle rigidity with the rat model.

From Matt Weinger:

I had expressed an interest in human factors and how it applied to anesthesia equipment. Early in my fellowship, Ty asked me to review a paper in Journal of Clinical Monitoring on vigilance.

After reading my review Ty suggested that I write an editorial with Nik Gravenstein, fostering that connection and giving me my first publication. Later that year, Ty helped me to find Dr. Carl Englund (at the Naval Medical Research Center in San Diego) with whom I wrote my first review article in Anesthesiology on this topic.

From Ted Eger:

Ty was a pleasant (to me at least), easy to work with researcher, careful and meticulous, who taught me what little I know about the ballistocardiagram, a device he protected with all his powers.

My association with him caused me to wear sandals in my life from our association forward. We had finished an experiment and I was dragging one of the H cylinders used to supply the pressurized air needed to power the BCG. I had not screwed the cap on carefully and when it separated from the cylinder I stupidly put out my foot to break the fall of the tank. I remember thinking this is going to hurt in two seconds, and it did. The swelling lasted several weeks and the only comfortable footware was sandals which I soon learned to appreciate for other reasons.

PACEM **Pacific Academy of Ecclesiastical Music**
Directors

I've loved music ever since I can remember, from "conducting" the kindergarten band to singing boy soprano in some very small performances, to being allowed to march and play the snare drum with the junior high band while still in elementary school. Music had to wait, however, while I engaged in sports and academics in high school.

Things started to change in college. The college radio station would broadcast "Music 1," and I listened intermittently with considerable fascination, but little understanding. The medical school dormitory had a library with LP records of classical music. I used to wake up in the middle of the night listening to the scratch of the needle at the end of the record.

PACEM **Pacific Academy of Ecclesiastical Music**
Directors

During college and university, music was the one luxury. Being self-taught meant that years were required to learn about music.

After a year or so of listening, one of my proudest moments came when I heard a new piece and recognized the composer (Beethoven's Seventh).

With PACEM, we want to ensure that children of all ages can learn about, enjoy and love music, with nothing but the finest as teachers and examples.

Start early; learn a lot.

The Measures of a Man

Ty Smith

Temperature in many tissues, stomach contents, ventilation, cardiac output, total peripheral resistance, mean transit time, stroke volume, left ventricular work, atrial contraction, pentobarbital, potassium, lidocaine, calcium, citrate, halothane, enflurane, isoflurane, oxygen, carbon dioxide, nitrous ocide, propranolol, hydralazine, histamine, rigidity, ballistocardiogram, pneumocardiogram, analog EEG, digital processed EEG, analog computer analyses, digital computer analyses, accuracy of simple and complex physiologic models, accuracy of open loop drug administration, accuracy of closed loop drug administration, muscle rigidity, measures of predictive performance, evoked potentials, human performance in medical simulators,