Donald P. Bernstein

Bernstein-Osypka stroke volume equation for impedance cardiography: citation correction

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Sir: Suttner et al. [1] are to be congratulated on a well designed and comprehensive study comparing thermodilution cardiac output (TDCO) to the results obtained from a recently introduced, state-of-the-art, cardiac output computer, utilizing the technology of transthoracic electrical bioimpedance. As correctly stated by the authors, the computer implements the Bernstein-Osypka stroke volume equation. Unfortunately, however, the authors have inadvertently misquoted reference 12 in their paper [2], which they offer as a valid citation for presentation of the Bernstein-Osypka equation and the concept of $dZ/dt_{\max}$ being an ohmic analog of mean aortic blood acceleration. In fact, nowhere in that review paper [2] is the Bernstein-Osypka equation or the acceleratory origin of $dZ/dt_{\max}$ discussed. As correctly cited by Schmidt et al. [3], which is reference 16 in the paper of Suttner et al. the equation was first introduced and published in 2003 as a United States patent (no. 6:511:438 B2, 28 January 2003; D.P. Bernstein,

M.J. Osypka, 2003, "Apparatus and method for determining an approximation of the stroke volume and the cardiac output of the heart"). Within the scope of the patent, a variation of the core Bernstein-Osypka equation was published as a peer-reviewed article in July 2005. In that paper the theoretical assumptions, derivation, and rationale for the new equation were presented, including a comparison study with TDCO in post-operative cardiac surgery patients. Shortly after publication of [4] the second peer-reviewed paper, that of Schmidt et al. [3], appeared. As Suttner et al. did not insert the equation into their methods section, the following abbreviated version of the Bernstein-Osypka equation is offered for archival purposes in the journal:

$$SV_{B-O} = \frac{V_{ITBV}}{\zeta^n} \sqrt{\frac{dZ/dt_{\max}}{Z_0}} T_{LVE(c)}$$

where V_{ITBV} = intrathoracic blood volume (ml), ζ = index of transthoracic aberrant electrical conduction, $dZ/dt_{\max}$ = peak rate of change of the blood resistivity (velocity) component of the transthoracic cardiogenic impedance pulse variation (ohmic mean acceleration) (Ωs^{-2}), Z_0 = transthoracic base impedance (Ω), $\sqrt{(dZ/dt_{\max})/Z_0}$ = acceleration step-down transformation (s^{-1}), $T_{LVE(c)}$ = heart rate-corrected left ventricular ejection time(s) [1, 3]. In [4] T_{LVE} is implemented without heart rate correction.

References

1. Suttner S, Schollhorn T, Boldt J, Mayer J, Rohm KD, Lang K, Piper SN (2006) Noninvasive assessment of cardiac output using thoracic electrical bioimpedance in hemodynamically stable and unstable patients after cardiac surgery: a comparison with pulmonary artery thermodilution. *Intensive Care Med* 32:2053–2058
2. Osypka MJ, Bernstein DP (1999) Electrophysiologic principles and theory of stroke volume determination by thoracic electrical bioimpedance. *AACN Clin Issues* 10:385–389
3. Schmidt C, Theilmeier G, Van Aken H, Korsmeier P, Wirtz SP, Berendes E, Hoffmeier A, Meissner A (2005) Comparison of electrical velocimetry and transoesophageal Doppler echocardiography for measuring stroke volume and cardiac output. *Br J Anaesth* 95:603–610
4. Bernstein DP, Lemmens HJM (2005) Stroke volume equation for impedance cardiography. *Med Biol Eng Comput* 43:443–450

D. P. Bernstein (✉)
Palomar Medical Center, Anesthesia,
555 East Valley Parkway, Escondido 92025,
CA, USA
e-mail: strokevolumedon@aol.com
Tel.: 858-7569379
Fax: 858-7568285