J Tokyo Wom Med Univ
78 (10・11) 474～478 (2008)

Original

Obese Patient Has Less Intravascular Volume: Intravascular Volume and Fat Free Mass Measured by Computed Tomography

Koichi SUGHIMOTO

Department of Cardiovascular Surgery, Kanto Medical Center NTT EC

(Accepted Sep. 19, 2008)

Background: It has been difficult to estimate a true patient's intravascular volume. Although about 99% of basic metabolic consumption is conducted in the non-fat tissues, the cardiac index itself does not include a fat effect and may predict inappropriate value in obese patients. This study evaluates the efficacy of the method excluding fat effect using computed tomography imaging to estimate the intra-vascular volume. **Methods and results**: Fat mass was obtained from the images of computed tomography and fat free mass was calculated by reducing the fat mass from the body weight. Intravascular volume was gained with a dilution method by the records of the cardiopulmonary bypass. Correlation between the fat free mass and the intravascular volume was assessed and statistic analysis was performed. There was a significant correlation between the fat free mass and the intra-vascular volume. **Conclusion**: Using computed tomography to calculate fat free mass, correlates well with the intravascular volume. Considering the result of this study, the Intra-vascular volume of obese patients would be low, thus the indicated Cardiac index value by Swan-Ganz catheter should be underestimated.

Key words: cardiopulmonary bypass (CPB), computed tomography, heart physiology, imaging and postoperative care

Introduction

Perioperatively, the intravascular volume (IVV) balance control is important and it is always necessary to adjust the ideal intravascular volume. Conventionally, cardiac index (CI), obtained with a Swan–Ganz catheter is used to evaluate the cardiac function, and the ideal volume balance is estimated with this index associated with other parameters or findings, such as heart rate, urination volume, or pulmonary artery pressures or patient's peripheral temperature. CI: cardiac output (CO)/body surface area (BSA) does not include the effect of the fat tissues. It is well-known that up to 99% of the body metabolism takes place in the non-fatty tissues, including tendons, ligaments, and bone. Therefore the fat free mass (FFM) is the major metabolically active tissue[1)2)]. Several previous papers reported the correlation between CO and FFM which was obtained by echo cardiograph and impedance meter[3)~6)]. However, CO is not constant but changeable often even in the intensive care unit with patients in stable condition, and also CO is the parameter associated with many factors, like catecholamines or daily activities. Measurement of the fat mass is now prevailed in the field of metabolic internal medicine to estimate the degree of obesity or used to help treat these obese patients. Impedance meter is commercially available material to calculate the somatic fat ratio, however, it is not used in the cardiovascular field yet because of mechanical limitations[7)8)]. The method to assess the fat mass with computed tomography (CT) imaging is more reliable and the feasibility is reported[9)10)]. In our institute as in other institutes in Japan, in almost all cases, CT scanning is performed to evaluate preoperative patient's lesion, such as calcification of the vessel or abnormality and it plays a very important role when making a cardiac operation strategy.

In this study, the correlation between FFM obtained with CT and IVV gained with a dilution method was examined and statistically analyzed. We anticipated that IVV for each patient could be easily provided from one umbilical slice of CT image with this correlation lines.

Materials and Methods

Since March 2001 to April 2004, there were 158 cases that underwent a cardiac operation using cardiopulmonary bypass (CPB), in our institute. Among the 158 cases using CPB, 42 cases were used in this study to fulfill the criteria: abdominal fat area (AFA) with complete CT image at the umbilical axial slice was measured; and the intravascular volume could be calculated by dilution method in the retrospective way. Those 42 cases were classified into 5 groups: 1) aortic regurgitation (AR); 5 males (M) and 6 females (F), 2) aortic stenosis (AS); 4 M and 6 F, 3) mitral regurgitation (MR); 4 M and 6 F, (4) mitral stenosis (MS); 1 M, and congenital (C); 4 M and 6 F. Group C consisted of the patients in atrial septal defect (ASD) or ventricular septal defect (VSD) (Table 1).

Table 1 Group classification

Group	Age	Gender (M/F)	N
MR	61+/−10	4/6	10
MS	49	1/0	1
AR	61+/−14	5/6	11
AS	71+/−2	4/6	10
C	48+/−16	4/6	10

42 cases were divided into 5 groups.
MR: mitral regurgitation, MS: mitral stenosis, AR: aortic regurgitation, AS: aortic stenosis, C: congenital heat disease (ASD, VSD).

This study was approved by the Ethics Committee in our institute with the patient's informed consent waived because of the retrospective study.

1. Measurement of Fat Free Mass

Images obtained preoperatively with 4 lines multi-slice CT: GE Light Speed QX/i-d (General Electric, Milwaukee, WI) were re-established on the image software: GE. Advantage Workstation 4.0, Volume Analysis (General Electric, Milwaukee, WI). One axial slice of CT images at the umbilical height was analyzed for this study with the conventional method[9)~11)]. CT numbers in Hounsfield units from −190 to −30 which indicate the fat CT density was extracted, and AFA was calculated with the software (Fig. 1). Then the body fat mass was estimated with the following Despres's equation: $TBF = 0.05234 \times AAT + 2.8788$ in adult males, $TBF = 0.0593 \times AAT + 1.6589$ in adult females (TBF: total body fat, AAT: abdominal adipose tissue)[12)]. FFM was calculated by reducing the body fat mass from actual body weight: FFM (kg)=BW (kg)−TBF (kg) (BW: body weight).

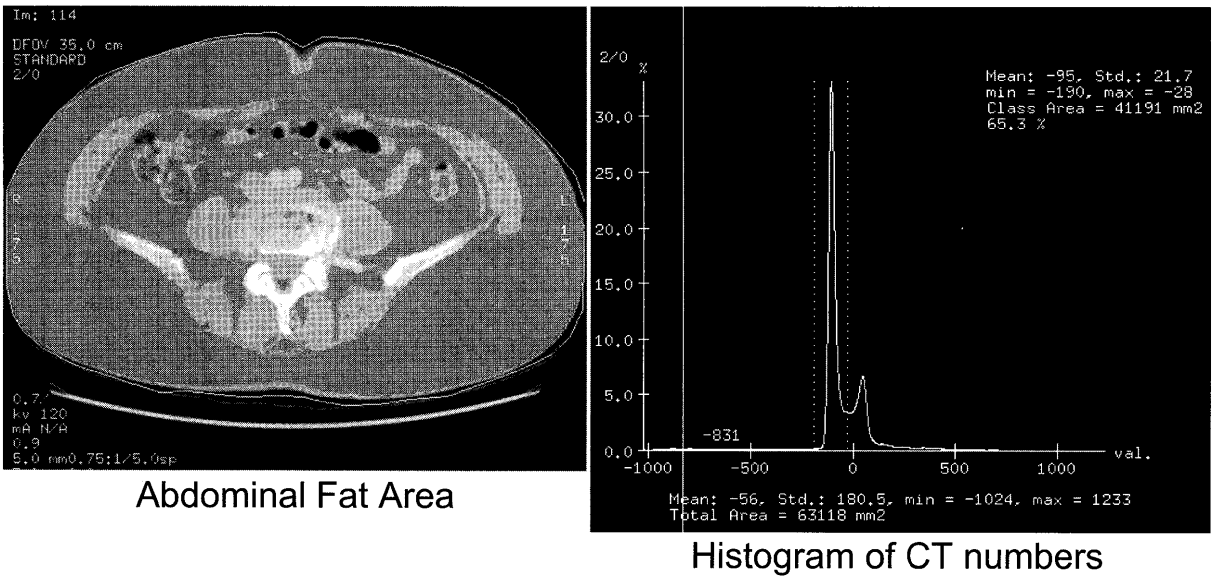

Fig. 1 One axial slice of CT images at the umbilical height
CT numbers in Hounsfield units from −190 to −30 which indicates fat CT density was extracted, and abdominal fat area (AFA) was calculated with the software.
CT: computed tomography.

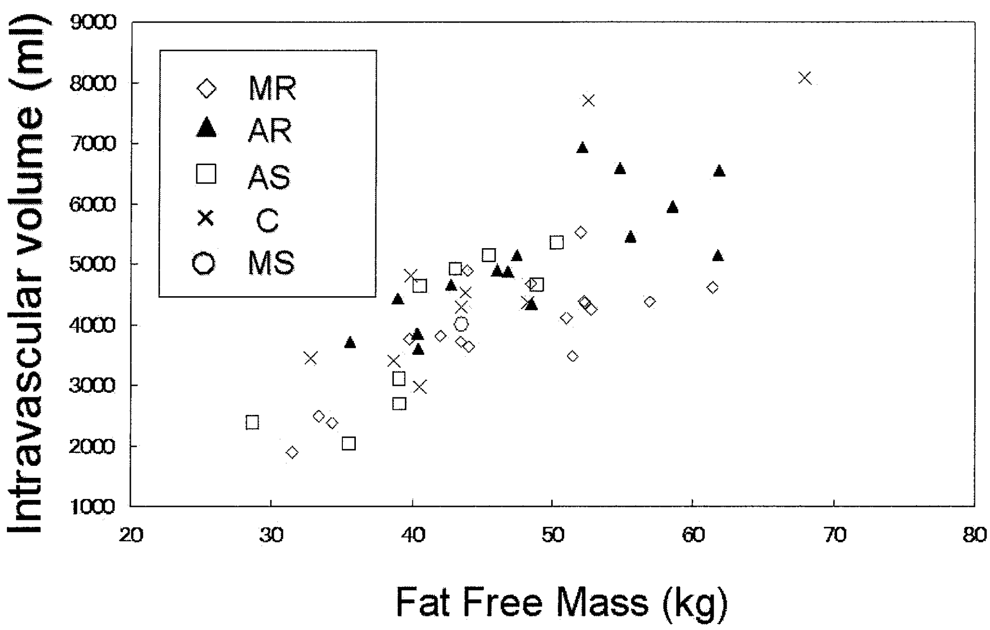

Fig. 2 Distribution between fat free mass and intravascular volume
Pearson's correlation coefficient was 0.767, which suggested strong correlation between FFM and IVV. p value was less than 0.0001.

2. Measurement of Intravascular Volume

IVV was calculated by using the diluting method in the operating room at the time of CPB. Blood samples were taken from the patient three minutes after 0.1 ml/kg of intravenous heparin administration and three minutes after the initiation of CPB. Almost all the cases the time between the two sampling points were less than 10 minutes, therefore the inlet-outlet water balance and the water shift into the interstitial tissues were ignored. Between the two points, the red blood cell counts were defined to be constant, thus this equation is achieved as follows: IVV×Hct (pre)=(IVV + diluting water)× Hct (post) (Hct: hematocrit, pre: 3 minutes before heparin dosage, post: 3 minutes after CPB initiation). Hence, IVV is calculated as follows: IVV=(Hct (post)×diluting water)/(Hct(pre)−Hct (post)).

3. Statistical analysis

Statistical analysis was performed with statistical software, Statview 5.0 (SAS Institute Inc. Cary, NC) to assess correlations between FFM and IVV in each group. The correlation was examined using Pearson's correlation coefficient examination. Linear regression examination was done between the FFM and IVV in each group. The significance level in this study was $p<0.05$.

Results

The distribution between FFM and IVV is described in Fig. 1. There was a tendency of the distribution in each group (Fig. 2). Pearson's correlation examination was done and good correlation was observed. The correlation score was 0.767, indicating strong correlation between FFM and IVV with p value less than 0.0001. A regression analysis was done in each group and the regression line was drawn (Fig. 3). In Table 2, Group C has the highest coefficient of determination (R^2) value of 0.758. In total, the equation was $y=117.58x-989.01$ with R^2 value of 0.5887 (Table 2). The distribution between BSA and IVV was also investigated. The R^2 value was 0.4744, the correlation of FFM against body weight, height or BSA was lower than that between FFM and IVV in any of groups (Table 3).

Discussion

An attempt to detect the appropriate intravascular volume has been done for many decades. Although several materials and machines are already available commercially, they are not necessarily sufficient in the medical field. Managing the postoperative volume balance is greatly supported by the continuous measurement of CI obtained by Swan–Ganz catheter. Although CI is standardized by di-

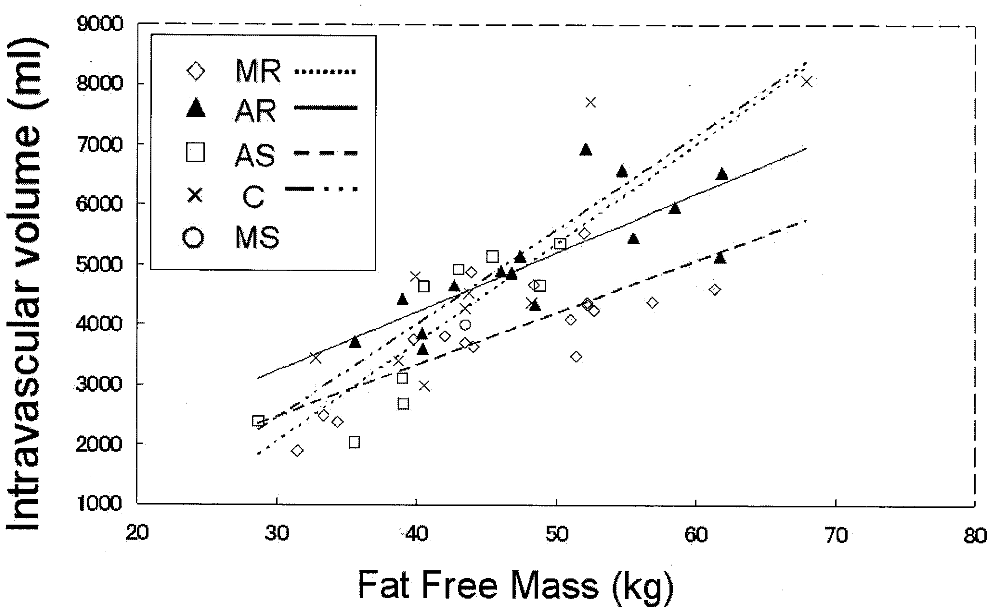

Fig. 3 The regression lines between fat free mass and intravascular volume
The highest coefficient of determination was 0.7584 in group C.

Table 2 Regression lines between fat free mass and intravascular volume

Group	Equation	R^2
MR	y = 86.93x − 141.9	0.607
AR	y = 98.36x + 283.7	0.610
AS	y = 165.03x − 2901.2	0.714
C	y = 156.84x − 2262.1	0.758
total	y = 117.58x − 989.01	0.589

Group C has the highest coefficient of determination (R^2) value of 0.758.

Table 3 Correlation between intravascular volume and height, body weight, and body surface area

Group-Correlation	R^2
MR-HT	0.44
-BW	0.32
-BSA	0.44
AR-HT	0.73
-BW	0.42
-BSA	0.54
AS-HT	0.50
-BW	0.36
-BSA	0.58
C-HT	0.64
-BW	0.65
-BSA	0.68

HT: height, BW: body weight, BSA: body surface area.

viding CO by BSA, the fat mass effect is not taken into consideration. Apparently, there is a great difference of the FFM between non-obese man and obese man even though they have the same BSA. We attempted to eliminate the fat effect from the body mass and to elucidate if FFM can correlate to IVV. For preoperative risk evaluation such as vessel calcification or some kinds of abnormalities, CT imaging plays an important role in cardiac surgery recently although the patient is exposed to the ionizing radiation; CT scan is performed in almost all cases in our institution as is other institutions in Japan. The software attached to CT scanner enables to calculate abdominal fat area easily and FFM are calculated with a slice of CT images. In this study, the correlation between IVV and FFM was evaluated, good correlations were observed and equation line was obtained. By this method, the patient's IVV would be easily predicted from one slice of the preoperative CT images. Considering the result of this study, the IVV of obese patients would be low, thus the indicated CI value by Swan-Ganz catheter should be underestimated. We often encounter the fact that an inadequate CI is indicated despite the patient's systemic circulation is kept stable providing adequate urination. At that time, we should recall the fat effect. This study supports the idea that an obese patient has lower IVV and thus lower CI. There were several limitations in this study. The numbers of patients were small, the lesion and the grade of the cardiac disease varied, not simplified;

for example, patients undergoing coronary artery bypass grafting (CABG) were not included because mainly the off-pump CABG was mainly performed in our institution. Technical limitations also existed: to measure intravascular volume, dilution method was used in the operating room; the blood sampling chance was limited. In measuring FFM, only one slice of CT image was used to calculate the FFM. Future and larger studies are needed to authorize this theory.

Limitations

This method is the statistical approach, the reliance of this study has statistical limitations. In this study, the numbers of patients were limited, and all the patients were suffering from some kind of cardiac disease, while the IVV of those who had ischemic heart disease would rather resemble to a healthy human being. IVV were measured during the operation with the patient anesthetized and the blood samples were withdrawn when the patients' hemodynamics were stabilized, the data might be influenced by the anesthesia.

References

1) **Roubenoff R, Kehayias JJ**: The meaning and measurement of lean body mass. Nutr Rev **46**: 163–175, 1991
2) **Moore FD**: Energy and the maintenance of body cell mass. J Parenter Entreral Nutr **4**: 228–260, 1980
3) **Collins T, Devereux RB, Roman MJ et al**: Relations of stroke volume and cardiac output to body composition: the strong heart study. Circulation **103**: 820–825, 2001
4) **Horlick M, Arpadi SM, Bethel J et al**: Bioelectrical impedance analysis models for prediction of total body water and fat-free mass in healthy and HIV-infected children and adolescents. Am J Clinl Nut **76**: 991–999, 2002
5) **Bella JN, Devereux RB, Roman MJ et al**: Relations of left ventricular mass to fat-free and adipose body mass: the strong heart study. Circulation **98**: 2538–2544, 1998
6) **Kuch B, Hense H-W, Gneiting B et al**: Body composition and prevalence of left ventricular hypertrophy. Circulation **102**: 405–410, 2000
7) **Kushner RF**: Bioelectrical impedance analysis: a review of principles and application. J Am Coll Nutr **11**: 199–209, 1992
8) **Davies PSW, Preece MA, Hicks CJ**: The prediction of total body water using bioelectrical impedance in children and adolescents. Ann Hum Biol **15**: 237–240, 1988
9) **Tokunaga K, Matsuzawa Y, Ishikawa K et al**: A novel technique for the determination of body fat by computed tomography. Int J Obes **7**: 437–445, 1983
10) **Sjöstrom L, Kvist H, Cederbblad A et al**: Determination of total adipose tissue and body fat in women by computed tomography, 40K and tritium. Am J Physiol **250**: E736–E745, 1986
11) **Kvist H, Chowdhury B, Sjostrom L et al**: Adipose tissue volume determination in males by computed tomography and 40K. Int J Obes **12**: 249–266, 1988
12) **Despres J-P, Ross R, Lemieux S**: Imaging techniques applied to the measurement of human body composition. *In* Human Body Composition (Roche AF, Heymsfield SB, Lohman TG eds) pp149–166, Human Kinetics, Champaign, IL (1996)

肥満患者における血管内容量は少ない
—血管内容量とCTにより算出した非脂肪重量の関係—

NTT東関東病院心臓血管外科

杉本（スギモト）　晃一（コウイチ）

〔背景〕患者の正確な血管内容量の推定はこれまで困難とされてきた．基礎代謝のおよそ99%が非脂肪組織で行われるにも拘わらず，心系数においては脂肪の影響は考慮されておらず，特に肥満患者においては適切でない値を推定している可能性がある．本研究ではCT画像を用いて脂肪の影響を除外し，血管内容量を推定する方法の有効性を評価するのが目的である．〔方法と結果〕CT画像より脂肪重量が得られ，体重より脂肪重量を引くことで非脂肪重量を算出した．血管内容量は人工心肺の記録から血液希釈法にて得た．非脂肪重量と血管内容量の相関関係を評価し，統計学的解析を行った．その結果，非脂肪重量と血管内容量には強い相関関係を認めた．〔結論〕CT画像により算出した非脂肪重量は血管内容量と良い相関を示した．今回の結果を考慮すると，肥満患者の血管内容量は低いと予想され，Swan-Ganz catheterにより得た肥満患者の心系数も過小評価している可能性がある．