Direct Calorimetry Using Swan-Ganz Catheter for Evaluation of General Metabolic Expenditure in Acute Cerebrovascular Disease

—Comparison Between Direct Fick Method and Indirect Calorimetry Technique—

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Abstract

Oxygen consumption calculated by the direct Fick method using a Swan-Ganz catheter ($D\text{-}\dot{V}O_2$) and indirect calorimetry using a metabolic computer ($ID\text{-}\dot{V}O_2$), carbon dioxide production calculated by the latter method, and respiratory quotient were determined pre- and postoperatively in 12 patients with acute hypertensive intracerebral hemorrhage and eight patients with acute ruptured intracranial aneurysm. The mean $D\text{-}\dot{V}O_2$ value was slightly lower than the mean $ID\text{-}\dot{V}O_2$ value, but had a significantly positive correlation. The regression curve was very close to the line of identity. The total metabolic expenditure can be calculated from $D\text{-}\dot{V}O_2$ and daily urinary nitrogen excretion. Direct calorimetry using a Swan-Ganz catheter is a simple method to evaluate metabolic expenditure in acute hemorrhagic cardiovascular disease.

Key words: direct Fick technique, indirect calorimetry, Swan-Ganz catheter, hemorrhagic cerebrovascular disease, metabolism

Introduction

Increased metabolic expenditure and negative nitrogen balance are characteristics of the hypercatabolic state accompanying thermal injury, infarction, trauma, shock, malignancy, and surgery.^{2,3,5-7,10,11,13,17,18} These result in malnutrition, causing rapid weight loss, high incidence of infection, suppressed immune response, and poor wound healing.^{1,8,20,22} Severe head injury is associated with an increased metabolic rate, which may result in failure to supply sufficient nitrogen and calories, with subsequent immunoincompetence and systemic organ failure. Recent studies of the metabolic response in acute head injury and hemorrhagic cerebrovascular diseases have been applied to clinical management.^{22,24,25} The indirect calorimetry technique using the Douglas bag or metabolic computer can be used to measure the general metabolism.^{15,28} Balloon-

tipped, flow-directed pulmonary artery catheters are widely used in the care of critically ill patients to obtain various cardiopulmonary hemodynamic data.²³ The direct Fick technique can measure the oxygen consumption rate as well as the hemodynamic parameters.²⁷

We compared the energy expenditure calculated by the direct Fick technique using a Swan-Ganz catheter with that measured by indirect calorimetry technique using the metabolic computer in patients with acute hemorrhagic cerebrovascular disease, and discuss the usefulness of the Fick technique for evaluating general metabolism.

Clinical Materials and Methods

Eight patients with ruptured intracranial aneurysm and 12 patients with hypertensive intracerebral hemorrhage were admitted to our department within 8 hours of ictus from April, 1989 through December, 1989. The mean age was 60.2 ± 11.4 years (mean $\pm$ SD) with a range of 42–85 years. Their body tempera-

tures ranged from 36.1 to 38.0°C. Physical examination revealed hypertension (> 160/100 mmHg), disturbance of consciousness, and neurological deficits. No patient had received corticosteroids or adrenergic blocking agents before or during metabolic expenditure measurements.

Immediately after admission, the body weight and height were measured to calculate the body surface area.⁹⁾ A 7-Fr Swan-Ganz catheter (American Edwards Laboratory, Irvine, Cal., U.S.A.) was inserted *via* the internal jugular vein. The metabolic expenditure was measured by the indirect calorimetry technique, and calculated using a metabolic computer (Medical Graphics Co., St. Paul, Minn., U.S.A.). The patients breathed spontaneously during measurements for about 15 minutes after resting quietly for at least 20 minutes. Oxygen consumption was calculated by the direct Fick method ($D-\dot{V}O_2$) and indirect calorimetry ($ID-\dot{V}O_2$), and indirect carbon dioxide production ($ID-\dot{V}CO_2$) and respiratory quotient (RQ) were calculated using the standard formulas.¹²⁾

I. Indirect calorimetry^{15,28)}

$$\dot{V}_E \text{STPD} = \dot{V}_E \text{ATPS} \times (P_B - P_{H_2O})/760 \\ \times 273/(273 + T)$$

$$ID-\dot{V}O_2 = \dot{V}_E \text{STPD} \times [(1 - F_{E}CO_2 - F_{E}O_2) \\ \times F_{I}O_2 / (1 - F_{I}O_2) - F_{E}O_2]$$

$$ID-\dot{V}CO_2 = \dot{V}_E \text{STPD} \times F_{E}CO_2$$

$$RQ = ID-\dot{V}CO_2 / ID-\dot{V}O_2$$

$\dot{V}_E$: expiratory volume, STPD: standard temperature, pressure, dry, ATPS: atmospheric temperature, pressure, saturated, P_B : barometric pressure, T : atmospheric temperature, P_{H_2O} : partial pressure of H_2O at T , $F_{I}O_2$: inspiratory oxygen fraction, $F_{E}O_2$: expiratory oxygen fraction, $F_{E}CO_2$: expiratory carbon dioxide fraction.

II. Direct Fick method^{14,16,27)}

$$D-\dot{V}O_2 = CO \times (CaO_2 - CvO_2) \times 10$$

$$CaO_2 = 1.39 \times HGB \times SATa/100 \\ + 0.0031 \times PaO_2$$

$$CvO_2 = 1.39 \times HGB \times SATv/100 \\ + 0.0031 \times PvO_2$$

CO: cardiac output, CaO_2 : oxygen content in arterial blood, CvO_2 : oxygen content in mixed vein, HGB: hemoglobin concentration, SATa: saturation of oxygen in arterial blood, SATv: saturation of oxygen in mixed vein, PaO_2 : partial pressure of oxygen in arterial blood, PvO_2 : partial pressure of oxygen in mixed vein. The SATa and SATv were measured with a hemoximeter (OSM2 Hemoximeter, Radiometer, Copenhagen, Denmark) and the PaO_2 and PvO_2 with an ABL3 (Radiometer). CO was

Fig. 1 Oxygen consumption calculated by the direct Fick method ($D-\dot{V}O_2$) has a significantly positive correlation with values calculated by indirect-calorimetry ($ID-\dot{V}O_2$) in 20 patients with hemorrhagic cerebrovascular disease ($p < 0.001$).

measured by the thermodilution method using 5 ml iced saline injectate, and a cardiac output computer (Nihon Kohden Co., Tokyo). These measurements were carried out 3 times at intervals of about 1 minute. The $D-\dot{V}O_2$ was calculated using the mean CO. The values for $D-\dot{V}O_2$ are expressed at 37°C, but the $ID-\dot{V}O_2$ and $ID-\dot{V}CO_2$ values calculated by indirect calorimetry are at STPD.

Results

The mean $D-\dot{V}O_2$ value (198.0 ± 28.8 ml/min) was slightly lower than for $ID-\dot{V}O_2$ (199.8 ± 27.3 ml/min). $D-\dot{V}O_2$ had a significantly positive correlation with $ID-\dot{V}O_2$ ($p < 0.001$) (Fig. 1). The regression curve was very close to the line of identity. The RQ and $ID-\dot{V}CO_2$ values were 0.84 ± 0.01 and 167.8 ± 22.8 ml/min, respectively.

Discussion

Levinson *et al.*¹⁶⁾ compared $ID-\dot{V}O_2$ and $ID-\dot{V}CO_2$ with $\dot{V}O_2$ measured simultaneously by a standard thermodilution technique in 29 mechanically ventilated patients. The two methods correlated well but $ID-\dot{V}O_2$ was 15% higher.¹⁶⁾ However, Head *et al.*¹⁴⁾ compared indirect calorimetry with direct calorimetry in spontaneously breathing patients and found a mean difference of less than 1%. The consistent underestimation of $\dot{V}O_2$ by the thermodilution tech-

nique is probably due to the slow thermistor equilibration relative to the catheter and the presence of thrombus.¹⁹⁾ Turner *et al.*²⁶⁾ measured $\dot{V}O_2$ by the direct Fick method at STPD. The $D\text{-}\dot{V}O_2$ value was about 8% lower than the value by indirect calorimetry.

Our results had a significantly positive correlation. The regression curve between the $\dot{V}O_2$ measurements was very close to the line of identity.

The $\dot{V}CO_2$ can be calculated when the $D\text{-}\dot{V}O_2$ and $ID\text{-}\dot{V}O_2$ are equal, and the RQ is about 0.84. If the urinary nitrogen is measured, the total metabolic expenditure (TME) can be calculated by the following formula²⁸⁾:

$$\begin{aligned} \text{TME (Cal/day)} \\ = 5.66 \times D\text{-}\dot{V}O_2 + 1.61 \times ID\text{-}\dot{V}CO_2 \\ - 2.15 (\text{urinary nitrogen excretion} + 2) \end{aligned}$$

Since approximately 2 gm of nitrogen is daily lost in the feces and from the skin, total nitrogen loss is estimated as urinary nitrogen loss plus 2.⁴⁾

In summary, direct calorimetry using the Swan-Ganz catheter is a simple method to evaluate metabolic expenditure in acute hemorrhagic cerebrovascular disease.

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