Metabolic Profile of Patients after Elective Open Heart Surgery

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To evaluate the surgical stress of open heart surgery with moderate hypothermic cardiopulmonary bypass (CPB), oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), resting energy expenditure (REE), respiratory quotient (RQ), 24 hour-urinary urea nitrogen excretion (UUN), and glucose, fat and protein utilization were determined in 20 patients before and after open heart surgery. Proteins (albumin, prealbumin and transferin) and body weight were measured preoperatively and on 6th postoperative day (POD). Preoperative predicted EE as determined by the Harris-Benedict equation was correlated with measured REE. No significant alteration in $\dot{V}O_2$, $\dot{V}CO_2$, REE, 24 hour UUN and protein utilization was observed on the first 6 PODs. RQ decreased significantly on the 1st, 3rd and 4th POD. This was attributed to greater fat utilization due to reduced calorie intake during the early postoperative period. Transport proteins reduced slightly but insignificantly. There was a significant reduction in body weight at the end of the study period due probably to loss of body water. We conclude that patients in the early postoperative period after uneventful open heart surgery are neither hypermetabolic nor hypercatabolic when compared with their stable state before operation. (Key words: Metabolic profile, open heart surgery)

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Open heart surgery with moderate hypothermic cardiopulmonary bypass (CPB) introduces significant alterations in physiological homeostasis not found in other major surgical procedures[1,2]. An increase in oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) during the immediate postoperative period have been reported[3,4]. However, there is little information published regarding the metabolic profile of this group of patients after the first postoperative day (POD). This study was designed to investigate prospectively the metabolic profile [$\dot{V}O_2$, $\dot{V}CO_2$, resting energy expenditure (REE), respiratory quotient (RQ), urinary urea nitrogen (UUN) excretion and serum transport proteins] from the 1st POD to the 6th POD in a group of patients who had open heart surgery performed under moderate hypothermic CPB (26°C).

Materials and Methods

With the approval of our institu-

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tional ethics committee and informed consent from patients, twenty patients (9 males and 11 females) who underwent open heart surgery [coronary artery bypass graft (CABG) n=8; mitral valve replacement (MVR), n=6; atrial septal defect (ASD) repair, n=6] under moderate hypothermic CPB were included in this study. All the patients had stable cardiac status (New York Heart Association Class II or III) and were not in cardiac failure before surgery. Patients with excessive postoperative bleeding which required reopening of the chest and those with pneumothorax were excluded from the study.

Measurement of metabolic parameters

$\dot{V}O_2$, $\dot{V}CO_2$, RQ and REE were determined preoperatively and from 1st POD (after extubation) to 6th POD. $\dot{V}O_2$ and $\dot{V}CO_2$ were measured by a gas exchange monitor, Deltatrac (Datex/Instrumentarium, Helsinki, Finland). Deltatrac is an open system indirect calorimetry device designed for measurements of $\dot{V}O_2$ and $\dot{V}CO_2$ in both spontaneously breathing and mechanically ventilated patients. All the measurements in this study were performed when the patients were breathing spontaneously. RQ and REE were calculated from $\dot{V}O_2$ and $\dot{V}CO_2$ measured by Deltatrac [EE=5.50 $\dot{V}O_2$ ($ml \cdot min^{-1}$) + 1.76 $\dot{V}CO_2$ ($ml \cdot min^{-1}$) −1.99 UUN ($grams \cdot 24h^{-1}$)][5]. The values for $\dot{V}O_2$ and $\dot{V}CO_2$ are updated by the Deltatrac every minute; $\dot{V}O_2$ and $\dot{V}CO_2$ are expressed under standard conditions: dry gas at 0°C and 760 mmHg (STPD). $\dot{V}O_2$ and $\dot{V}CO_2$ were measured twice a day while the patients were resting in bed (7 am and 5 pm, before breakfast and dinner respectively). Each measurement period was about 40 minutes and the average of the mean values of the two periods was taken to represent a mean value ($ml \cdot min^{-1}$) of the day. The daily estimated REE was compared to the actual daily caloric intake as assessed by our dietician during the study period. Preoperatively, the REE measured by Deltatrac was compared to predicted EE calculated by the Harris-Benedict formula[6].

Twenty-four-hour urine specimens were taken as accurately as possible and the UNN was measured in our clinical laboratory. Appropriate adjustments to this value were made if there were significant alterations in blood urea nitrogen levels from the previous day. Daily substrates utilization were calculated using the following formula[7].

$$ds=4.115\,\dot{V}CO_2-2.909\dot{V}O_2 -2.539\,N$$

$$df=1.689\,(\dot{V}O_2-\dot{V}CO_2)\,-1.943\,N$$

$$dp=6.25\,N$$

where ds, df, dp = grams of totally metabolized carbohydrate, fat and protein per minute respectively. N = urea nitrogen production ($g \cdot min^{-1}$).

Anaesthesia, CPB and postoperative management

Anaesthesia was induced with fentanyl (20 $\mu g \cdot kg^{-1}$) and midazolam (0.1 $mg \cdot kg^{-1}$). Pancuronium bromide (0.1 $mg \cdot kg^{-1}$) was used to facilitate endotracheal intubation. Anaesthesia was maintained with a mixture of oxygen: nitrous oxide (50:50) in an open circuit system. Additional doses of fentanyl and pancuronium were given intraoperatively. CPB was instituted with a membrane oxygenator (COBE laboratories Inc. Arvada, C080004 USA) primed with lactated Ringer's solution and oxygenated with a mixture of air and oxygen. CPB was initiated at normothermia with a pump flow rate of 2.2 $L \cdot min^{-1} \cdot m^{2-1}$, moderate hypothermia (rectal temperature of 26°C) was induced with a heat exchanger.

Postoperatively, all the patients were mechanically ventilated (Siemens Elema, 900C) with a minute volume

Table 1. Duration of cardiopulmonary bypass (CPB) and age of three groups of patients.

	MVR n=6	CABG n=8	ASD n=6
CPB (min)	68 ± 14.1	100 ± 22.4[a]	36.6 ± 12.5[b]
Age (yr)	44 ± 13.2	57 ± 5.1[c]	25.8 ± 17.2

a – significant when compared to ASD (P <0.001) and MVR (P=0.003)

b – significant when compared to MVR (P=0.01)

c – significant when compared to MVR (P=0.02) and ASD (P=0.001)

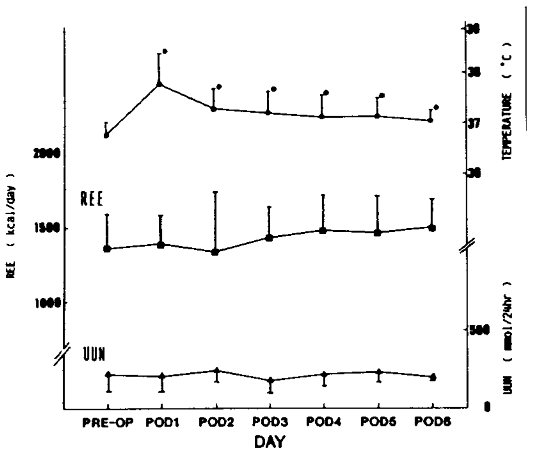

Fig. 1. Resting energy expenditure (REE), 24 hour urinary urea nitrogen (UUN) excretion and oral temperature of all patients from preoperative (preop) day to the sixth postoperative day (POD). Significant difference designated by *($P < 0.05$) when compared with preoperative.

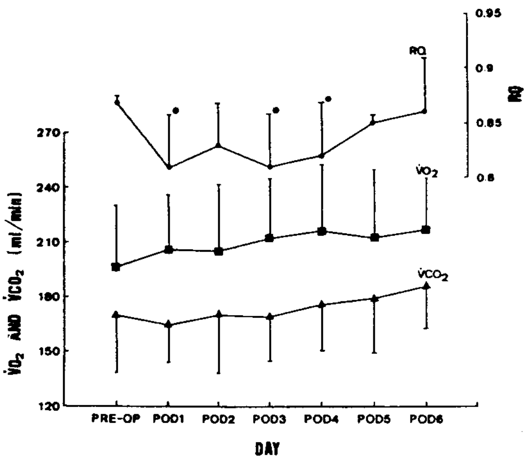

Fig. 2. Oxygen consumption ($\dot{V}o_2$), carbon dioxide production ($\dot{V}co_2$) and respiratory quotient (RQ) of all patient from preoperative (preop) day to the sixth postoperative day (POD). Significant difference designated by *($P < 0.05$) when compared with preoperative value.

and a fraction of inspired oxygen to obtain a Pa_{O_2} of 80–120 mmHg and Pa_{CO_2} of 30–40 mmHg. Intravenous boluses of diazepam and infusion of morphine and sodium nitroprusside were used to provide sedation, analgesia and blood pressure control. All patients were extubated 12 to 16 hours after the end of surgical procedures.

All patients received intravenous 5% dextrose and 0.45% sodium chloride infusion during the first two POD (1.5 $L{\cdot}m^{2-1}$). Oral intake were resumed on the 1st POD after extubation, oral furosemide (lasix) 20 mg twice daily was then started for a week. Body weight, serum albumin, prealbumin and transferrin were measured preop-

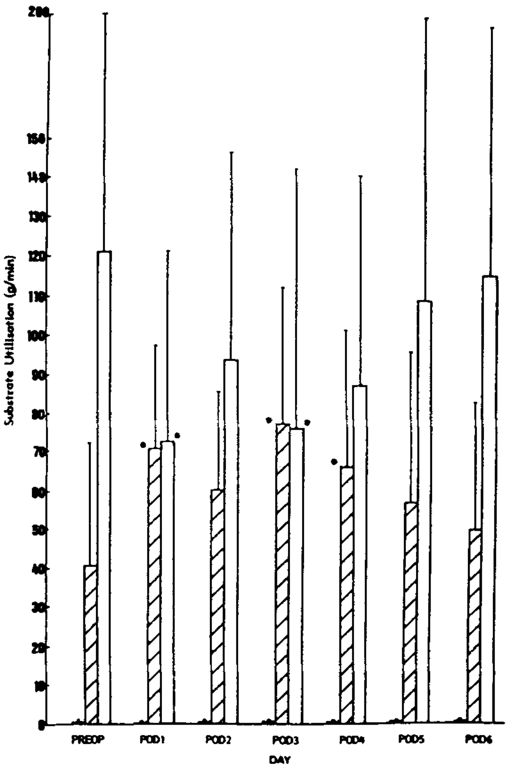

Fig. 3. Substrate utilization of all patients from preoperative (preop) day to the sixth postoperative day (POD). Significant difference designated by *($P < 0.05$) when compared with preop values ■, protein; □, fat; ▨, carbohydrate.

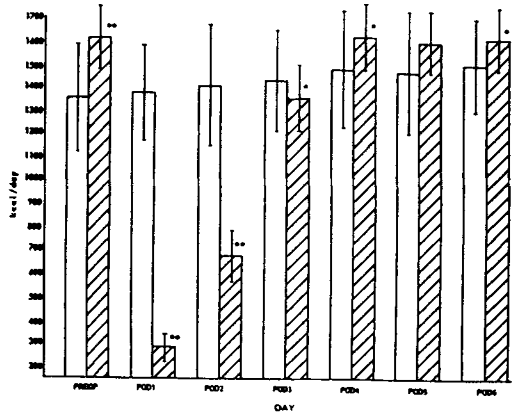

Fig. 4. Preoperative and postoperative measured resting energy expenditure (REE) and caloric intake depicted in graphic form. □, measured REE; ▨, actual caloric intake, significant difference designated by *($P < 0.05$) and **($P < 0.01$) when compared with actual caloric intake.

eratively and on the 6th POD. Room temperature in the intensive care unit (ICU) and in the ward was 23°C–25°C.

Two-ways analysis of variance (ANOVA) was used to test for any significant difference among groups. Variables within each group were compared using one-way ANOVA and the least significant differences test. Linear regression analysis was used to compare preoperative REE and predicted EE. A P value of less than 0.05 was taken as statistical significant. All values were expressed as mean ± SD unless stated otherwise.

Results

The CABG group was significantly older and had undergone a significantly longer CPB as compared to other 2 groups (table 1). All the variables of 3 groups of patients (CABG, ASD and MVR) were initially analysed separately and compared to one and other. As there were no significant differences among the 3 groups, the data were pooled and analysed as one single group.

Despite a minor elevation in oral temperature (fig. 1) there was no significant change in $\dot{V}O_2$, $\dot{V}CO_2$, REE and 24 hour UUN excretion over the entire study period (fig. 1, 2). However, the RQ values on the 1st, 3rd, and 4th POD were significantly lower when compared with the preoperative RQ (fig. 2). The utilization of fat was significantly higher and the utilization of carbohydrate was significantly lower on the 1st, 3rd and 4th POD when compared with preoperative values (fig. 3). The actual caloric

Table 2. Body weight, albumin, prealbumin and transferin measured preoperatively (preop) and on the sixth postoperative day (POD). Values in parenthesis indicate normal reference values.

	Pre-op	6th POD
Body Weight (kg)	58.1 ± 13	54.8 ± 12.1*
Albumin (30–55 g·l)	41.3 ± 2.7	37.9 ± 4.2
Prealbumin (17–42 mg·dl^{-1})	28 ± 5.6	23.9 ± 10.1
Transferrin (240–360 mg·dl^{-1})	264.8 ± 47	255.4 ± 29

$*P < 0.0001$

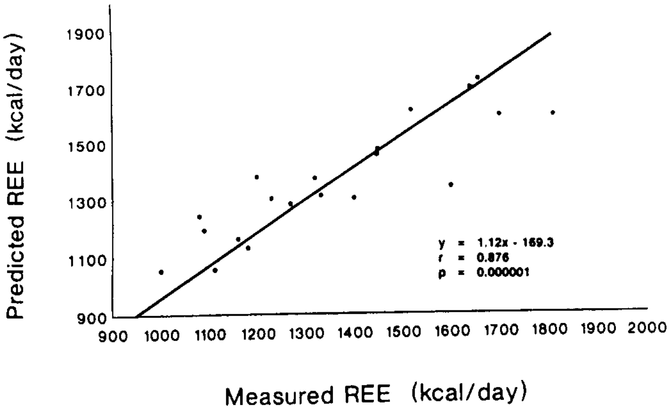

Fig. 5. Relationship between predicted energy expenditure (EE) and measured resting energy expenditure (REE).

intake was significantly lower than the measured REE on the 1st, 2nd and 3rd (fig. 4).

Albumin, prealbumin and transferin measured on the 6th POD were not significantly different from their preoperative values. However, there was a significant decrease in body weight on the 6th POD when compared to preoperative body weight (table 2). There was a good correlation between the preoperative measured REE and the predicted EE (r=0.876) (fig. 5).

Discussion

This study showed that there was no significant variation in $\dot{V}O_2$, $\dot{V}CO_2$ and REE up to the 6th POD after uneventful open heart surgery performed under moderate hypothermic CPB. Although the Harris-Benedict equation or other formulae for estimating EE[6,8,9] can predict actual values within ± 10%[10]; estimated values obtained from these equations differ from the actual energy expenditure in many pathological conditions such as injury, sepsis, burns and malnutrition[11]. Therefore, in order to assess postoperative EE accurately, we measured REE for all our patients individually. REE was measured without regard for the time of day or the relation to food intake, it also include components due to physical or psychological stress and variation in ambient or body temperature[12].

The method of choice for measuring REE is indirect calorimetry, which is based on measurements of $\dot{V}O_2$, $\dot{V}CO_2$ and nitrogen excretion. Recent advancement in micro-electronics has produced portable instruments used to measure $\dot{V}O_2$ and $\dot{V}CO_2$ by the bedside. The gas exchange monitor (Deltatrac) used in this study has recently been validated[13].

Urea is a main nitrogen–containing component of urine and non-urea nitrogen compounds are thought to be excreted at a relatively constant rate for different clinical states[14]. Many clinicians use the measurement of UUN to estimate total urinary nitrogen which is useful to determine a patient's amino acid requirements. As it was not our intention to perform nitrogen balance studies in our patients, we used UUN to estimate protein catabolism and to calculate substrate utilization. It is interesting to note that though $\dot{V}O_2$, $\dot{V}CO_2$ and REE did not increase significantly over the entire period of study, RQ values on 1st, 3rd and 4th POD were significantly lower when compared with preoperative RQ. The decrease in the RQ values were probably due to greater fat utilization as a result of relative starvation (fig. 4) during the immediate postoperative period. Fat oxidation resulted in greater $\dot{V}O_2$ than $\dot{V}CO_2$, the disproportionate increase in $\dot{V}O_2$ as compared to $\dot{V}CO_2$ resulted in lower RQ values. Calculation of substrate utilization confirmed that utilization of fat was significantly higher on the 1st, 3rd and 4th POD as compared to preoperative state (fig. 3).

Protein utilization and 24 hour UUN excretion did not change significantly despite reduced caloric intake during the first three days after operation. This could be due to the constant infusion of 5% Dextrose solution during the first 2POD, as dextrose has been known to be a very potent sparer of nitrogen[15]. The resumption of oral intake by the end of 1st POD is also a major contributory factor to prevent excessive protein catabolism.

Our patients were not malnourished preoperatively; there was no history of recent weight loss and their nutritional markers (albumin, prealbumin and transferin) were all within normal limits. The 3 nutritional markers reduced slightly but not significantly when measured on the 6th POD. Despite the lack of evidence for increased EE and protein catabolism, our patients lost body weight of about 4 kg during the period of study. We attributed the loss in body weight to the loss of body water as a result of diuretic therapy and fluid restriction, which are part of our routine post-cardiac surgery management protocol. We could not, however, dismiss that part of weight loss might be due to loss of fat or protein in the tissue as detailed measurement of body composition was not performed. The good correlation between the preoperative measured REE and the predicted EE support the validity of the method.

Savino J, et al.[16] determined the energy requirements of 20 patients suffering from valvular heart disease. REE was measured using indirect calorimetry similar to ours before and 47 days following valvular surgery. The measured REE was also compared to the predicted REE calculated by the Harris Benedict equation. They found that majority of their valvular heart disease patients were hypermetabolic (i.e. energy requirements underestimated by predictive formulas), and surprisingly their energy requirements remain elevated post valve surgery despite improvement in functional status. The disparity in the results may be due to the different functional cardiac status of the 2 population of patients. Savino J, et al.'s patients were classified as Class III or IV by the New

York Heart Association classification, as compared to our patients who were classified as Class II or III (4 valvular heart disease patients). Therefore, some of their patients may be suffering from sever chronic heart failure which is known to be associated with serious weight loss and cachexia because of elevation of the metabolic rate[17]. Furthermore, our patients population is more heterogenous as compared to Savino J, et al's patients who were all suffered from valvular heart disease. We feel that patients who are suffering from valvular heart disease complicated by chronic heart failure and cardiac cachexia may benefit from actual measurement of their energy requirement. The result can be used to guide perioperative nutritional intake, so as to avoid complications associated with over or underfeeding.

In conclusion, uneventful open heart surgery performed under moderate hypothermic CPB did not result in significant alteration in $\dot{V}O_2$, $\dot{V}CO_2$ and REE during the first 6 POD. Short term reduction in caloric intake in the immediate postoperatively period did not cause significant change in protein utilization and 24 hour UUN excretion.

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References

1. Abe T: Influence of cardiac surgery using cardiopulmonary bypass on metabolic regulation, Jpn Circ J 38:13–17, 1974.
2. Hirvonen J, Huttunen P, Nuutinen L, et al: Catecholamines and free fatty acids of patients undergoing cardiac operations with hypothermia and bypass. J Clin Pathol 31:949–955, 1978.
3. Raison JCA, Osborn JJ, Beaumont JO, et al: Oxygen consumption after open heart surgery measured by a digital computer system. Ann Surg 171:471–484, 1970.
4. Chiara O, Giomerelli PP, Biagioli B, et al: Hypermetabolic response after hypothermic cardiopulmonary bypass. Crit Care Med 15:995–1000, 1987.
5. Deltatrac MBM-100, Operator's Manual Revision 01, Manual No. 877870. Datex/Instrumentarium Corp. Helsinki, Finland. June 1990, p. E-5.
6. Harris JA, Benedict FG: A biometric study of basal metabolism in man. Washington DC, Carnegie Inst Wash, Publ No. 279, 1919.
7. Bursztein S, Glaser P, Trichet B, et al: Utilization of protein, carbohydrate and fat in fasting and postabsorptive subjects. The American Journal of Clinical Nutrition 33:998–1001, 1980.
8. Boothby WM, Berkson J, Dunn HL: Studies of the energy metabolic of normal individuals. Am J Physiol 116:468–484, 1936.
9. Aub JC, DuBois EF: Clinical calorimetry. The basal metabolism of old man. Arch Int Med 19:823–831, 1917.
10. Feurer ID, Crosby CO, Mullen JL: Measured and predicted resting energy expenditure in clinically stable patients. Clin Nutr 3:27–34, 1984.
11. Kinney JM, Duke JH Jr, Long CL et al: Tissue fuel and weight loss after injury. J Clin Path 23 (Suppl):65–72, 1970.
12. Bursztein S, Elwyn DH, Askanazi J, et al: Energy metabolism, indirect calorimetry, and nutrition. Baltimore, Williams and Wilkins, 1989, pp. 30–31.
13. Takala J, Keinanen O, Vaisanen P, et al: Measurement of gas exchange in intensive care: laboratory and clinical validation of a new device. Crit Care Med 17:1041–1047, 1989.
14. Lee HA, Hartley TF: A method of determining daily nitrogen requirements. Postgrad Med J 51:441–445, 1975.
15. Gamble JL: Physiological information gained from studies on the life raft ration. Harvey Lect 42:247–273, 1946.
16. Savino J, Agarwal N, Gordon D, et al: Increased energy expenditure in valvular heart disease patients. Crit Care Med 15:446, 1987.
17. Braunwald E: Heart failure in Harri-

son's Principles of Internal Medicine edited by Petersdorf RG et al, 10th edition. New York, McGraw Hill Inc. 1983, p. 1357.