METABOLISM AND BASAL METABOLISM
Their Significance in Anesthetic Administration

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Metabolism

Metabolism may be defined as "the sum total of the physical and chemical processes that are associated with the maintenance of life in the animal organism." Metabolism may be divided into two groups of reactions: (1) anabolism, or the building up of tissue elements for use or storage, and (2) catabolism, or the breaking down of tissue elements into simple materials for systemic use.

Foods that have been ingested are eventually absorbed from the intestine and are then oxidized to produce materials that supply energy for tissue activity (muscular, nervous, secretory energy, etc.), to supply heat, and to build new tissue elements (the synthesizing of proteins, fats, carbohydrates, etc.). The formation of these energy substances is called anabolism.

When these tissue elements are broken down into simpler forms for systemic utilization (as when during fasting fat is withdrawn from the cells in which it is deposited and used as a source of energy), that phase of metabolism is called catabolism.

Howell briefly defines anabolism as "energy storage" and catabolism as "energy dissipation" in the form of work or heat.¹

Since heat is produced during all cellular activity, the heat production of an organism is intimately related to, and is a measure of, its metabolism. One method of determining the metabolic rate (energy requirement) of an animal is to measure accurately the total amount of heat produced by the total organism during a given period. The apparatus for heat production determinations is called a calorimeter. A simpler method of determining metabolic rate consists in determining the amount of oxygen consumed by a person during a given period. This method is less accurate but is better adapted for clinical use than the calorimeter method.

The rationale of using oxygen consumption as an indicator of metabolic rate is that almost all body heat is produced by the combining of nutritional material with oxygen, i.e., the oxidation of foodstuffs in the body; therefore, the amount of oxygen consumed may be regarded as a measure of the amount of heat produced. The apparatus employed for making this type of determination is called a met abolimeter.

Basal Metabolism

The term basal metabolism is used to describe the rate of energy transformation, i.e., the energy requirement, in an animal organism during its minimal awake activity—at as nearly complete rest as possible and while the organism is subsisting on its own food stores. It represents the amount of ox-

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idation taking place while the fires of the body are banked, or, as one writer puts it, "the calories being used to run the machine, when no work is being done by it." It is not to be regarded as the lowest possible rate of energy exchange, because during sleep heat production falls approximately 10-13 per cent below the basal level. For this reason, basal metabolism may be measured only while the subject is awake.

In man, this determination is made not earlier than 12 hours after ingestion of the previous meal and while the person lies perfectly still in a comfortably warm room, so that voluntary muscles, other than those of respiration, are entirely at rest and have been so for half an hour. The meal eaten at least 12 hours previously has been digested and assimilated, and no energy is being used to perform external work. Very little energy is being used to build new tissue. Metabolism is reduced to the maintenance of circulation, respiration, etc., the general equilibriums of vital processes, and of a constant body temperature. The minimal energy requirement is being furnished by oxidation of stored substances, and the person is said to be in a basal state, his rate of heat production being termed his basal metabolic rate.

As has been said, the basal metabolic rate of heat production is usually stated clinically in terms of its corollary, the basal metabolic rate of oxygen consumption. According to Guedel, the curve of cell oxygen demand parallels that of metabolism. Although this figure is a less precise gage of metabolic activity than is an actual laboratory measurement of heat production, the results are adequate for diagnostic purposes, which merely compare them with an average rate of metabolic activity that has been established by the study of large groups of similarly typed persons.

For persons of similar age, the basal metabolic rate (heat production and therefore fuel requirement of the body) is proportionate to the surface area of the body and not to body weight. For a normal male, aged 20-30, the average basal metabolic rate is 40 calories of heat per hour per square meter body surface. After age 30, the basal metabolic rate slowly declines. During the period of early growth, around age 5, a much higher basal metabolic rate prevails. The basal metabolic rate of females is approximately 10 per cent lower than that of males.

Tables of standard or average basal metabolic rates, determined by various technics, have been published by different investigators from time to time. The following tables, compiled as one, are illustrative.

The Boothby, Dunn, and Berkson study is probably as comprehensive as any that has been made to date.

For clinical purposes, a person's basal metabolic rate is expressed in terms of per cent above or per cent below the average for his sex and age group. "Plus 16" indicates that the subject's basal metabolic rate is 16 per cent higher than the average for his sex and age group. "Minus 16" indicates that the subject's basal metabolic rate is 16 per cent lower than the average for his sex and age group.

Although this means of expressing a subject's metabolic activity is simple and convenient and adequate for clinical purposes, it is less precise than the

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<tr>
<th>Age in Years</th>
<th>Shimer, after Du Bois &amp; Benedict, J.A.M.A. Nov. 29, 1924</th>
<th>Krogh Modification of Russell Sage Institute of Pathology (Aub-Du Bois) Standards</th>
<th>Boothby, Dunn &amp; Berkson, Mayo Clinic Tables, 1936</th>
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The expression of basal metabolism in terms of heat production per sec (in calories per hour) or in terms of liters of oxygen consumed per hour. For instance, the designation "normal basal metabolic rate" for an obese person merely indicates his normalcy in relation to his sex and age group. It fails to indicate the metabolic rate characteristic of all obese persons in his group, all of whom, by reason of their obesity (and concomitant increased surface area) evidence a higher than normal metabolic rate, which would be immediately apparent if his metabolic rate were expressed in terms of liters of oxygen per hour or calories per square meter per hour, rather than in terms of normalcy for his group.

**Significance of Metabolism in Anesthetic Administration**

Differences in patients' metabolic rates reflect corresponding differences in their need for oxygen for tissue oxygenation. This fact may be related to the administration of anesthetics. A patient with a metabolic rate as low as 35 calories, as a result of premedication, advanced age, or other causes, may require only 15 per cent oxygen in the respired mixture to satisfy his tissue metabolic needs, whereas a patient with a metabolic requirement as high as 50 calories or more, as a result of hyperthyroidism, another pathologic condition, or rapid growth, may require as much as 30 per cent oxygen in his respired mixture. Translated into terms of the clinical administration of an anesthetic by a closed carbon dioxide absorption method, the first patient might need only 250 cc. oxygen per minute, whereas the second patient might require 500 cc. oxygen a minute.

Such an increase in the oxygen content of a mixture can be made only at the expense of the anesthetic gas. Thus, merely as a result of the difference in metabolic rate, one patient could re-

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ceive an anesthetic mixture consisting of 85 per cent anesthetic gas and 15 per cent oxygen, whereas the other could receive not more than 70 per cent of anesthetic gas, because of the 30 per cent oxygen that would be required.

When potent anesthetic agents, such as ether, cyclopropane, and chloroform, are used, this high oxygen demand is not embarrassing. However, if a less potent agent, such as nitrous oxide, were used as the only agent, either an incomplete, light anesthesia or a distressing degree of anoxia would result.

Since oxygen demand and reflex irritability parallel metabolic rate, differences in metabolic rate are important in anesthesia since they represent fundamental differences in the amounts of oxygen required by different patients (1) for protection of vital life-sustaining metabolic processes and (2) to satisfy an increased metabolic rate that has been reflexly elevated by pain stimuli, which need must be fulfilled even though deeper narcosis may be indicated to inhibit the actuating pain stimuli.

These contradictory demands for full surgical anesthesia and at the same time for full oxygenation at the existing high metabolic rate may in part explain the clinical pre-eminence of the very potent anesthetic agents, ether and cyclopropane. They permit the conduct of deep surgical anesthesia and, at the same time, the provision of the wide margin of oxygenation required to protect the patient’s vital metabolic processes.

Some authors consider the patient’s basal metabolic rate the basis for selecting premedication as well as the anesthetic agent. Since emotional excitement due to fear, or muscular activity incident to emotional excitement, elevates the metabolic rate as much as 30 per cent according to Wiggers, premedication is directed at reducing emotional excitement. Barbiturates have been suggested for premedication, but since the dose of a barbiturate necessary to depress metabolism is large, the doses usually used for premedication have little effect on a patient’s metabolic rate.

Of the preanesthetic drugs in common use, opium derivatives are the most potent depressants of metabolism. They not only directly inhibit metabolism but also, by allaying pain, combat the elevation of the metabolic rate which would otherwise be caused reflexly. It has even been proposed that, instead of being determined routinely, the dosage of morphine be related to the metabolic rate, based upon the rationale that while ¼ gr. morphine might paralyze respiration in a patient with hypothyroidism and a low metabolic rate, the same dose would be insufficient for a patient with a high metabolic rate.

According to Cushing, basal metabolism in man is decreased about 10 per cent by therapeutic doses of morphine during the first hour after the injection is given.

Opiates are destroyed in the body at a rate in proportion to the metabolic rate of the patient. A patient with a greatly increased metabolic rate, such as is sometimes seen in postoperative

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nance Committee, Leone Theilen, chairman, Hazel Reed, and Melva Werking. A letter from Marie Kraft concerning national information of impending legislation and accompanying forms were shown to the members. At a previous meeting of the board of trustees, a motion was made to adopt the legislative mailing service. The secretary read a letter from the Executive Office concerning registration in the Wisconsin association of male nurses who are trained anesthetists. The president requested the secretary to write Ruth Bergman, Minneapolis, concerning male nurse anesthetists. Eletta E. Silver was appointed to investigate the establishment of a refresher course in anesthesia for Wisconsin anesthetists.

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thyrotoxic crisis, may destroy ¼ gr. morphine in one or two hours, whereas in a patient with a low metabolic rate, an aged patient, for example, 1/6 gr. may be effective for six to eight hours.

Atropine is a direct stimulant to metabolism. When balanced with mor- phine, however, this action of atropine is somewhat counteracted. It is proposed that morphine ¼ gr. plus atro- pine 1/150 gr. produces about the same metabolic depression as morphine 1/6 gr. without atropine.

According to Cushny, the cessation of many ordinary movements incident to the administration of curare reduces the metabolic rate of the patient. 5

The basal metabolic rate is abnormally high in patients with hyperthyroidism and is high in those with tuberculosis, diabetic acidosis, and cardiac decompensation, what Wiggers calls "decompensated stages of heart disease." 4 Since elevation of basal metabolic rate is associated with a corresponding elevation in basal oxygen consumption rate, patients with hyperthyroidism or tuberculosis obviously need a high oxygen supply.

Scopolamine is a direct stimulant of metabolism and in premedication reduces metabolism only to the degree that it reduces emotional excitement, the latter action being somewhat offset by its directly stimulating action on metabolism. Scopolamine markedly inhibits secretion of mucus. When scopolamine is used in properly balanced doses with morphine, the metabolic rate is lowered, and anesthesia is facilitated. However, when scopolamine overbalances the morphine, the metabolic rate is increased, and induction and conduct of the anesthesia are rendered more difficult.

SUMMARY

The preanesthetic metabolic rate of a patient gives a clue to the margin of oxygenation that must be provided during the anesthesia. It thereby denotes the potency of the anesthetic agent required. Metabolic rate may be favorably influenced by appropriate preanesthetic medication.

Dues for the current year were payable before Mar. 1. Members failing to pay dues by that time are liable to a $3 penalty fee. Members of organized state associations remit their dues to the treasurer of the state association. Members not affiliated with an organized state association remit their dues to the Treasurer's Office of the American Association of Nurse Anesthetists, 18 E. Division St., Chicago 10, Ill.

5. Ibid.

4. Loc. cit.