

Diabetes and Surgery

THE MANAGEMENT OF DIABETES in patients undergoing surgery is a subject that has tended to generate heat rather than light, as occurs in so many other areas of clinical practice.¹ The numbers of opinions expressed and options offered are in inverse proportion to the good data available. The relevant literature is distributed among specialist journals in the three areas of anesthesiology, surgery and diabetes, and it tends to be ignored if not in the appropriate sector.

Hirsch and his colleagues—a team with expertise in diabetes and anesthesiology—attempt to redress this imbalance in this issue of ANESTHESIOLOGY with an account of management that is reasonable and defensible. They point out that there is no consensus on the optimal metabolic management of the diabetic patient during surgery, and proceed to review the various current recommendations. They conclude that the regimen of Watts *et al.* of variable insulin² by separate infusion is the best for insulin-dependent diabetes mellitus (IDDM) patients undergoing inpatient surgery under general anesthesia.

The choice is less clear among recommendations for patients undergoing ambulatory surgery, for whom both subcutaneous (sc) and intravenous (iv) insulin are options. Similarly, there is lack of clarity regarding the choice of insulin regimen for non-insulin-dependent diabetes mellitus (NIDDM) patients, although there is agreement that insulin is needed if glycemic levels are unsatisfactory. Can clearer guidelines be offered? It should be remembered that the majority of diabetic patients undergoing surgery worldwide will not have the benefit of a specialist diabetes service or of anesthesiologists with a particular interest in minimizing morbidity and mortality. The more complex regimens, if necessary, should be reserved for the specialist centers.

The goals of metabolic care during surgery must be to attain at least the same outcome in terms of mortality and morbidity as in the nondiabetic patient. Hirsch *et al.*¹ suggest that normal metabolism should be mimicked as closely as possible. This suggestion is probably too rigid: the closer blood glucose is brought to normal, the greater the risk of hypoglycemia, which is the main avoidable complication of surgery in the diabetic. Obviously, excess catabolism is undesirable. The aim for control of glycemia should be to obtain glucose levels that are well above hypoglycemic levels but below those at which deleterious effects of hyperglycemia become evident. The latter include hyperos-

molarity, impaired wound healing,³ and disordered phagocyte function.⁴ In the past hyperglycemia has been avoided by giving no insulin at all,⁵ but this will allow unrestrained catabolism. Obviously, enough insulin is needed to provide the required anabolic effect, and glucose to achieve the desired safe blood glucose value. Hirsch *et al.* agree with my previously recommended target of 120–180 mg/dl.⁶ It should be noted that these values are whole-blood figures; if plasma is used, the target range becomes 140–200 mg/dl.

The main arguments defining any approach can be divided into those concerning preoperative assessment and care, perioperative treatment, and postoperative care. Initially, we recommended that diabetic patients, and those with IDDM in particular, should be admitted to the hospital 2–3 days before the operation.⁷ This had two aims—to allow good metabolic control to be achieved and to allow anesthetic risk to be assessed. This approach is costly and now deemed unnecessary. For the majority of patients, reasonable metabolic control can be achieved in a few hours, and his or her clinical state can be checked on an outpatient basis. The latter should include cardiovascular examination, measurement of renal function, and close examination for autonomic neuropathy. Autonomic neuropathy is common in diabetes and can lead to perioperative hypotension.⁸ Intraoperative cardiorespiratory arrest, presumably also secondary to autonomic neuropathy, also has been reported in diabetic patients.⁹

Another important aspect of preoperative care is review of drug and insulin regimens. Insulin is less problematic now that there are very few very long-acting insulins in use. Bovine Ultralente can present problems (delayed hypoglycemia), and it is probably sensible to stop it several days before operation and replace it with either the human preparation or an intermediate-acting insulin. Many patients now use injection pens and take multiple injections of short-acting insulin through the day with an intermediate-acting preparation at night. Such an approach can be continued until the morning of operation. Unlike Hirsch *et al.*, I would not omit the intermediate insulin on the evening before operation. Modern intermediate insulins have significantly shorter half-lives than previously, and omission inevitably leads to an overnight rebound in blood glucose.

The use of oral hypoglycemic agents also requires careful consideration. Metformin should be stopped at least 2 days before operation. This biguanide is used widely outside the United States and is safe except when there is renal impairment. However, it does cause hyperlactatemia, and renal function may deteriorate during anesthesia. The use of sulfonylureas should also be reviewed. It is sensible to stop long-acting agents 3 days

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before operation and replace them with short-acting agents. The former include chlorpropamide and glyburide (glibenclamide). The latter has been implicated as a particular cause of hypoglycemia in the elderly, who are the majority of those undergoing operation. Again in contrast to Hirsch *et al.*, I would omit all oral agents on the morning of operation.

Most of the controversy surrounds the most appropriate regimens to use during surgery itself. It cannot be overemphasized that whatever system is chosen, it should be used systematically and by all anesthesiologists within a given setting. This allows the nurses and junior medical staff to become familiar with one scheme and helps to prevent mistakes. Thai *et al.* have compared the use of such a scheme, supervised by an on-call diabetes team, with random choice determined by different anesthesiologists and surgeons.¹⁰ In the latter group (anesthesiologists and surgeons), one third of patients did not have blood glucose measured on the day of operation, whereas of those who did, 42% had levels above 220 mg/dl at some time on the day of operation, compared with 18% in the diabetes team-controlled group. Hypoglycemia was rare in both groups. Many problems, including use of inappropriate fluids and lack of insulin, were encountered in the random-treatment group, and were in great part due to confusion on the part of the nursing staff, who lacked clear instructions.

It is unanimous that IDDM patients undergoing major surgery should be treated with insulin, but should this be by iv or sc administration?¹¹ Carefully conducted comparative studies are few. There is still, surprisingly, widespread use of sc insulin even by major authorities. We found better control with an iv regimen, even before we had optimized our technique.¹² Recently, Pezzarossa and colleagues¹³ found better glycemic regulation only in the intraoperative period; it should be noted, however, that the majority of the patients they studied had NIDDM. Theoretically, there is no doubt that a continuous infusion of insulin iv is the preferred regimen. Insulin given sc is at best absorbed erratically, and with the blood pressure and blood flow variations that inevitably accompany anesthesia and surgery absorption, sc insulin cannot be other than variable and unpredictable. One reason for the continued use of sc regimens—and all of the guess work for glucose requirements that they entail—simply is custom. Results in well-practiced hands and with a team approach in major centers undoubtedly are adequate. In this setting, there is regular patient monitoring and proper surveillance so that any problems that emerge can be dealt with rapidly. This does not mean, however, that the sc approach is either logical or desirable. It is certainly more difficult and more hazardous than the simple iv regimens and is not suitable for average centers.

There is also some debate over which iv regimen to use. Hirsch *et al.* quite rightly point out that the use of

large iv boluses is irrational and unfounded. The main choice rests between the separate variable-rate insulin infusion and the combined glucose–insulin–potassium (GIK) infusion. Watts *et al.*² have obtained good results with the former, which, theoretically, is sensible. There are no data, however, from smaller centers on the use of this scheme. We tend to prefer the mixed GIK regimen and have obtained satisfactory results.¹⁴ Initially, we used too low a ratio of insulin to glucose¹² but have obtained better results since starting with an insulin/glucose ratio of 0.32 U/g. The disadvantage of the GIK regimen is that if it becomes necessary to change the amount of insulin, a new iv bag must be prepared. In the majority of patients, however, a change was unnecessary. The advantage is that if there is any variation in the rate of flow of the infusion, insulin and glucose delivery are affected equally. In contrast, if separate infusions are used, there can be catastrophic hyperglycemia or hypoglycemia if one infusion becomes blocked or speeds up. This is unlikely in well-staffed specialist centers but may present a real risk in the average hospital. I therefore urge that the GIK be the treatment of choice in the nonspecialized setting. Two GIK regimens have been proposed—one based on 10% glucose and one on 5% glucose, both given at 100 ml/h.⁶ Since the latter yields only 480 kcal per 24 h, I use the former, which provides double the calories and allows a slightly more anabolic amount of insulin to be given.

Regardless of the system used, regular monitoring of blood glucose concentrations is vital. Hirsch *et al.* monitor more often than is customary in the United Kingdom. I always routinely measure a fasting blood glucose concentration on the day of operation, using both test-strip or meter and laboratory analysis. This gives an instant result but also a later quality-assurance check. A further check is made preoperatively or every 2 h if the operation is delayed. For long operations, both an intraoperative measurement and an additional measurement in the recovery room are made. Thereafter, there is one measurement at 2 h postoperatively and then every 4 h. In practice, in uncomplicated operations on well-controlled subjects, one or two fewer measurements of blood glucose concentrations may be permissible.

The situation is less clear for IDDM patients undergoing minor surgery, although at my institution we have obtained better blood glucose control with GIK than with sc insulin.^{12,15} There seems little reason to use other than the GIK regimen if general anesthesia is to be used. GIK is simple and allows postoperative flexibility: it can be continued until the patient is ready to eat, at which time sc insulin can be reinstated. Many patients feel nauseated after anesthesia and may not wish to eat for some hours, even though the procedure may have been short. As Hirsch *et al.* point out, diabetic patients are more likely to have gastroparesis.

There is little question that NIDDM patients under-

going major surgery should also receive an iv insulin regimen, even if the diabetes is initially well controlled. The metabolic stress of surgery is sufficient to warrant this. If, depending on blood glucose levels, the choice is left to start the iv insulin later, the patient can become severely catabolic, and mistakes in management may be made.

There is less certainty with regard to NIDDM patients undergoing minor surgery. We have shown that for these patients, there is no advantage of GIK *versus* no insulin.¹⁷ The GIK group had slightly lower glucose levels but also showed lower levels of potassium and decreased levels of alternative fuels. We conclude that for this group, the simplest treatment is no specific therapy at all, providing that fasting blood glucose is 180 mg/dl or less. If the blood glucose is higher, then the standard GIK can be used.

The situation can be summarized therefore very simply. All diabetic patients having general anesthesia for minor or major surgery should be treated with an iv insulin infusion regimen, except for reasonably well-controlled NIDDM patients undergoing minor surgery. The regimen proposed by Watts *et al.*² is suitable for specialized centers, whereas the GIK is the simpler and safer approach for the majority of hospitals. At my institution, we use simple protocol sheets that are attached to the patient's chart the night before surgery and that state infusion requirements and request the appropriate glucose-monitoring schedule. Certain patients, such as those who are very obese, septic, or cirrhotic,⁷ can be predicted to need more insulin. In special situations, such as cardiac surgery, a different schedule is needed because of massive insulin resistance.¹⁸

For the majority of diabetic patients, it should be possible to prevent surgical morbidity and mortality and the length of the hospital stay from exceeding those for non-diabetic patients. Prospective studies are still needed to confirm several aspects of perioperative management of diabetic patients; until then, the advice offered in the current article by Hirsch *et al.* and in this editorial may provide some useful guidance.

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