Refining Perioperative Glucose Management in Patients Experiencing, or at Risk for, Ischemic Brain Injury

ISCHEMIC brain injury is the third leading cause of death in the United States, and survivors of ischemic brain injury represent the leading cause of major disability. Most of these ischemic events begin outside the hospital. However, patients who enter the hospital neurologically intact may experience new-onset cerebral ischemia, e.g., in association with cardiac or cerebrovascular surgery. Those who have experienced a single ischemic event (whether beginning outside or inside the hospital) are at risk for exacerbation of their injury during hospitalization due to secondary insults resulting from cardiac arrhythmias, systemic hypotension, surgical interventions, cerebral vasospasm, and other causes. During hospitalization, clinicians have many opportunities to lessen the risk of both primary and secondary ischemic injury. One such possibility is the disciplined monitoring and management of blood glucose concentrations. Although the issue of intensive insulin therapy and glycemic control is pertinent to critically ill patients in general, as addressed by Blasi-Ibanez et al., and reviewed by Lipshutz and Gropper in last month’s issue of ANESTHESIOLOGY, patients who have experienced or are at risk for ischemic brain injury represent a special population (for reasons we will later review). There is considerable, consistent evidence from animal models and human studies that outcome after a cerebral ischemic insult is partially modulated by blood and brain glucose concentrations. However, the current literature offers little guidance for the clinician on how to apply the existing data such that outcome can be optimized during the care of neurologically at-risk patients, particularly with respect to how rigidly glucose should be controlled and the magnitude of risk in executing such control. Two human studies reported in this issue of ANESTHESIOLOGY focused on this issue. Bilotta et al. report on the challenges and pitfalls of glucose management in patients requiring intracranial surgical procedures. Likewise, Thiele et al. report on the effect of institution of a strict blood glucose management protocol on outcome in critically ill patients with subarachnoid hemorrhage.

Glucose management in patients with cerebral insults in-evolution may be problematic. Specifically, physiologic stress, use of corticosteroids or other drugs (e.g., sympathomimetics), neuroendocrine disorders, nutritional support, and other factors may all combine to make the fine tuning of blood glucose concentrations difficult. Data from experiments in animal models inform us that modest changes in blood glucose concentrations, on the order of 40 mg/dl, are sufficient to modulate outcome after an ischemic insult. Further, optimum neurologic outcome, based on animal and human research, will likely occur at blood glucose concentrations of 130 mg/dl or less. However, it is unclear whether more rigorous glucose reduction is beneficial. Specifically, there is concern that hypoglycemia can cause irreversible brain injury and cardiovascular compromise independent of the presence of cerebral ischemia.

To address these challenges, Bilotta et al. prospectively studied 483 patients presenting for elective or emergent intracranial procedures. Patients were randomized to either intensive (target blood glucose concentration = 80–110 mg/dl) or conventional (target blood glucose concentration < 215 mg/dl) glycemic management. The primary goal of this investigation was to compare the rates of hypoglycemic episodes (blood glucose < 50 mg/dl) between groups. Other outcome metrics evaluated were length of intensive care unit stay, infection rate, 6-month Glasgow Outcome Score, and mortality. A greater fraction of patients in the intensive glucose treatment group had hypoglycemic episodes (94% vs. 63% for conventional treatment; P < 0.0001), but they also had a lesser incidence of infections (26% vs. 39% for conventional therapy; P = 0.002) and a shorter median duration of intensive care unit stay (6 days vs. 8 days; P < 0.0001). Despite these differences, there was no difference in 6-month Glasgow Outcome Scores (P = 0.984) or mortality (P = 0.689) between groups.

A related study in this issue of ANESTHESIOLOGY retrospectively reported on an intensive glucose control protocol introduced at the University of Virginia Health System on January 1, 2002. Target blood glucose concentration was 90–120 mg/dl. Thiele et al. compared clinical outcome in patients with subarachnoid hemorrhage managed before (1995–2001, n = 343) or after (2002–2007, n = 491) institution of the glucose-management protocol. Despite statistically positive results regarding glucose endpoints, the difference between preprotocol and post-protocol median blood glucose concentration was ex-
tremely small (121 mg/dl vs. 116 mg/dl, respectively; 
\( P < 0.001 \)). There was, however, a large difference in 
median admission blood glucose concentration through-
out the entire study period between survivors (135 mg/
dl) and nonsurvivors (176 mg/dl; \( P < 0.001 \)). It is un-
clear whether this association represents a cause-and-
effect relationship between glucose concentration and 
and injury or, instead, represents a stress response due to 
injury severity. Similar to Bilotta et al., hypoglycemic 
episodes in the Thiele et al. research (blood glucose 
concentration < 60 mg/dl) were more common in the 
tensively managed group (7.1% vs. 1.5%; \( P < 0.001 \)). 
Thiele et al. also reported that hypoglycemia was inde-
pendent associated with an increased risk of death (OR = 
3.82; 95% CI = 1.40–10.44; \( P = 0.009 \)); however, their 
research was unable to determine whether hyperglyce-
mia contributed to death or whether patients who were 
more likely to die were also more vulnerable to de-
veloping hypoglycemia (e.g., as a result of altered neuroen-
docrine function) during insulin treatment. Overall mor-
tality during hospitalization was not influenced by 
glycemic management protocol (\( P = 0.876 \)).

The studies of Bilotta et al.\(^{3}\) and Thiele et al.\(^{4}\) are 
similar to earlier studies of van den Berge,\(^{7}\) Krinsley,\(^{8}\) 
and Gandhi et al.\(^{9}\) that evaluated the feasibility of string-
ent glucose management in hospitalized patients. End-
points of these three studies were some combination of 
death and the incidence of medical complications, i.e., 
endpoints of most relevance to the type of nonneuro-
surgical patients being studied. Bilotta et al. and Thiele 
et al., studied neurosurgical patients in their reports in 
Anesthesiology, and (with the exception of assessing 
Glasgow Outcome Scores in the Bilotta et al. study) used 
endpoints similar to those of van den Berge et al.,\(^{7}\) 
Krinsley,\(^{8}\) and Gandhi et al.\(^{9}\) Consistent with the earlier 
studies, Bilotta et al. and Thiele et al. report that a modest 
fraction of patients experienced hypoglycemia. 
Whereas Bilotta et al. and Thiele et al. provided infor-
mation on some of the risks associated with aggressive 
glucose management in the neurosurgical patient popu-
lation, meaningful advancement of our understanding of 
the risks versus benefits of strict glycemic management 
will require the application of more discriminating 
metrics of outcome, particularly neurologic outcome.

Recent research in cardiac and cerebral aneurysm sur-
gery patients, i.e., populations at high risk for additional 
or new-onset neurologic injury, has determined that neu-
ropsychological changes, which require the use of 
highly sophisticated testing, are far more sensitive than 
the assessment of gross neurologic function, hospital 
stay data, or mortality rates in identifying brain injury.\(^{10,11}\) In 
their recent retrospective analysis of data from 1000 
patients entered into the Intraoperative Hypothermia for 
Aneurysm Surgery Trial database, Pasternak et al.\(^{11}\) re-
ported that aberrations of neuropsychological function were 
more common (i.e., incidences of 18–70%, de-
pending on the specific test being reported) than those of 
gross neurologic function (18–39%). Altered neu-
ropsychological function occurred at a lesser glucose con-
centration (i.e., \( \geq 129 \) mg/dl) than gross neurologic 
function (i.e., \( \geq 152 \) mg/dl) based on the National Insti-
tutes of Health Stroke Scale. Of note, Glasgow Outcome 
Score data were insensitive to glucose modulation, and 
mortality rate was independent of blood glucose concen-
tration (\( P = 0.09 \)) in the Pasternak et al. investigation. 
Similarly, in their study of glucose control in 409 cardiac 
surgery patients, Gandhi et al.\(^{5}\) determined that mortal-
ity rates alone were not influenced by glucose manage-
ment, and only the composite of mortality rate and the 
overall rate of a medical complication identified a statis-
tically significant result. Given these factors, it would 
seem that mortality rate is a crude, inadequate marker of 
glucose modulation of ischemic brain injury. Therefore, 
in terms of glucose modulation of outcome after an 
acute ischemic insult, future studies will be able to reach 
the strongest, most statistically clean and powerful, and 
most clinically relevant assessments when and only 
when they prospectively use formalized tests of gross 
neurologic function and neuropsychological function 
(and not some surrogates or mortality alone) to deter-
mine outcome.

Although the studies of Bilotta et al. and Thiele et al. 
address the feasibility of glucose management in patients 
experiencing or at risk for neurologic injury, neither as-
sessed long-term outcome using the tests now demon-
strated to quantify subtle glucose modulation of neurologic 
injury in neurosurgical patients (i.e., neuropsychological 
testing, the National Institutes of Health Stroke Scale). 
As such, these investigators still leave unanswered one of 
the most important glucose-management issues of the day: 
What is the likelihood that glucose management can affect 
neuropsychological function and subtle sensorimotor func-
tion in those who survive a cerebral insult? These issues 
can only be addressed with prospective, appropriately 
powered study designs that employ appropriate tests of 
both sensorimotor function and neuropsychological 
function known to be associated with alterations in 
glucose concentrations. Given the incidences of 
hypoglycemia reported by Bilotta et al. and Thiele 
et al. in neurosurgical patients, it is all the more impor-
tant that future outcome investigations rigorously and 
prospectively evaluate both gross neurologic function 
and neuropsychological function in patient subjected 
to strict glucose control.

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