Co-existing Diabetes Mellitus in Neurosurgical Patients

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18.1 Introduction

After a brief primary acute insult to the brain like head trauma, ischemia as in stroke, bleed as in intracranial hemorrhage (ICH), or subarachnoid hemorrhage (SAH), patients can suffer from a variety of secondary insults which aggravates the primary brain injury leading to poor outcomes including mortality. In addition, these secondary insults prolong the intensive care unit (ICU) and hospital stay with added cost of treatment. High degree of vigilance for prevention and aggressive management of these secondary aggravating factors form a major part of the perioperative as well as critical care pathways to improve the outcomes. Hyperglycemia is one of such frequent secondary insults that occur in these patients that need to be diagnosed and managed aggressively. Writing Committee of American Diabetes Association has classified hyperglycemia seen in hospitalized patients of three types: patients with known diabetes mellitus (DM), newly diagnosed DM, and hospital-related hyperglycemia due to the illness and which reverts back after discharge from hospital [1]. Hyperglycemia is seen in both neurosurgical and neurological diseases especially in acute stages of the disease process. The incidence of hyperglycemia is very high varying from 30 to 50% in patients with acute stroke, 69% in subarachnoid hemorrhage, 40% in head injured, 47% in ICU, and 32% in non-ICU hospitalized patients [2–5]. This chapter will enumerate the various pathophysiological, diagnostic, and therapeutic aspects of hyperglycemia occurring in brain disease.

18.2 Hyperglycemia in Hospital Setting (ICU and Non-ICU)

18.2.1 Stress Hyperglycemia

In patients admitted in the medical and surgical ICU and in the perioperative period, transient hyperglycemia is seen, especially without history of DM. This is termed "stress hyperglycemia" (SH). Initially the condition was thought to be insignificant. However, such hyperglycemia was found to be associated with increased morbidity, and aggressive treatment of hyperglycemia has been advocated [6]. The mortality rates were found to be higher for critically ill patients with newly diagnosed hyperglycemia in the hospital compared to normoglycemia as well as hyperglycemia in known patients with DM [7, 8]. The mechanism of stress hyperglycemia is thought to be due to complex interplay of counter-regulatory hormones like catecholamines, growth hormone, ACTH, and

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cortisol along with insulin resistance. Stress caused by various types of brain injury leads to enhance production of various inflammatory mediators like cytokines. Tumor necrosis factor-alpha (TNF) increases the production of glucagon which enhances hepatic production of glucose [9].

The inflammation and cytokines also cause insulin resistance which prevent hepatic formation of glucose as well as inhibition of insulin receptors (GLUT4) in the peripheral tissues causing poor uptake of glucose and reduced production of muscle glycogen from glucose [10]. In addition, the hyperglycemia itself suppresses immune function and increases the inflammatory mediators release causing further hyperglycemia [11]. There is enhanced lipolysis in tissues causing impaired insulin sensitivity. Hence stress hyperglycemia is characterized by glucose toxicity, lipotoxicity, and enhanced inflammation leading to endothelial dysfunction and organ damage.

18.2.2 Hyperglycemia in Head Injury

Since many years it has been well recognized that hyperglycemia occurs frequently in patients with head injury irrespective whether preexisting diabetes mellitus is present or not. In majority, the condition occurs as hyperosmolar nonketotic hyperglycemia. Presence of hyperglycemia has been associated with poor Glasgow coma scale score (GCS) and poor survival. The degree of hyperglycemia was found to be independent of the magnitude of raise in intracranial pressure [12]. Severe hyperglycemia was seen within 12 h of head injury and reduced in 36–48 h; however, there was a tendency for persistent mild hyperglycemia in the early phase of head injury till 5–7 days. The systemic hyperglycemia was found to correlate with CSF hyperglycemia and lactate levels [13].

In pediatric patients with closed head injury, Parish et al. found that transient hyperglycemia was also seen in children; an older study showed that the hyperglycemia was not associated with poor prognosis as seen in adult population with head injuries [14]. However, a recent study has found that severe hyperglycemia (>200 mg%) was associated with poor outcome in pediatric patients compared to mild hyperglycemia [15]. Another recent study has shown that early hyperglycemia was associated with increased hospital mortality and reduced ventilator free days and hospital stay in moderate to severe head injured paediatric patients [16].

18.2.3 Hyperglycemia in Stroke

Acute stroke is one of the leading causes of morbidity in the world, and high incidence of hyperglycemia is seen at admission regardless of whether they are diabetic or not. Patients presenting with admission hyperglycemia have been found to have poor National Insitiute of Health Stroke scale (NIHSS) score indicating the severity of stroke [17]. A cutoff value of admission glucose level of more than 143 mg% has been shown to increase short-term mortality in their study [17]. The etiology of hyperglycemia is thought to be due to stress induced. Admission hyperglycemia has been found to be associated with poor functional outcome, inadequate recanalization, and risk for hemorrhagic transformation following intra-arterial thrombolysis [18]. In addition to admission hyperglycemia, Osei et al. have found that presence of impaired fasting glucose as well as prediabetic state has been associated with poor outcome in patients with acute stroke for IA thrombolysis [18]. The pathogenic mechanism of hyperglycemia causing poor outcome is due to multiple etiology. Excess glucose in the presence of ischemia causes the mitochondria in neurons to produce more lactic acidosis via anaerobic pathway leading to intracellular acidosis and cell death [19]. This is particularly seen in penumbral regions. Moreover, hyperglycemia causes disruption of blood capillary barrier and blood brain barrier leading to increased brain edema and hemorrhagic transformation [20]. Hyperglycemia has also been thought to alter the cerebrovascular reactivity leading to poor recanalization following intra-arterial thrombolytic therapy.

18.2.4 Hyperglycemia in SAH

Hyperglycemia is frequently seen at admission in patients with SAH. The hyperglycaemia occurrence is thought to be due to the effect of brain injury. Hyperglycemia at admission as well as higher blood glucose values that were seen in the first 14 days following SAH has been found to be associated with higher 1-year mortality [21]. Poorer grade SAH is associated with higher admission hyperglycemia compared to good grades (Hunt and Hess) [22]. In addition to immediate and delayed poor outcome, mean hyperglycemia in the ICU has been associated with increased incidence of vasospasm, delayed cerebral ischemia, and prolonged stay in ICU [23]. However, recently it was found that in patients with SAH, glucose value of <80 mg/dl is associated with cerebral infarction, vasospasm, and worse functional outcomes [24]. Hence both hyper- and hypoglycemia were found to be detrimental in patients with SAH.

18.2.5 Hyperglycemia of Endocrinopathies

Hyperglycemia can be seen in patients with excessive secretion of pituitary hormones notably growth hormone (GH) and adrenocortical-stimulating hormone (ACTH). Hyperglycemia that occurs in acromegaly patients is due to glucose intolerance or diabetes mellitus. The incidence is estimated to be 12–37%. The etiology is thought to be due to both excessive levels of circulating GH and insulin-like growth factor (IGF-1) concentrations both of which cause insulin resistance. There is decreased glucose utilization as well as increased production of glucose [25]. Hyperglycemia seen in these patients has been associated with increased mortality compared to general population [26]. Patients with Cushing's disease also present with increased blood glucose. Up to 40–45% of patients with Cushing's disease have been reported to develop DM, and 10–30% of patients have impaired glucose tolerance [27]. Similar to acromegaly, these patients also have insulin resistance as well as increased production of glucose by liver which is responsible for hyperglycemia.

18.2.6 Other Conditions

Hyperglycemia is also seen in acute phase of variety of other neurological conditions like intracranial bleeds due to various etiology, central nervous system infections like acute meningoencephalitis, spinal cord injuries, status epilepticus, sepsis, etc. Use of high dose of steroids and immunosuppressive therapies for the treatment of various neurological conditions are also associated with hyperglycemia in ICU and non-ICU hospitalized patients. A single dose of dexamethasone has been found to cause hyperglycemia in the perioperative period in neurosurgery [28]. It has been suggested to monitor the blood glucose concentration for 12–24 h in a nondiabetic patient who has been administered dexamethasone for craniotomy.

18.3 Effects of Hyperglycemia on Brain

Glucose is the main source of energy for the brain under normal conditions. Brain glucose concentration is approximately two thirds of plasma concentration, and it is shown to rise with hyperglycemia. The effects of hyperglycemia in injured brain are multifactorial. Hyperglycemia, hypoglycemia, and greater fluctuations in plasma glucose levels have been proven to aggravate brain injury. Increased plasma glucose occurring both in acute conditions like SH as well as chronically seen in DM affects produce both structural and functional brain abnormalities. In acute states, hyperglycemia produces intracellular increase in lactate (acidosis) leading to apoptosis. In addition, it was found that acute hyperglycemia causes microvascular changes, reduced BBB permeability, reduces cerebral blood flow, and worsens ischemia [29]. Clinically hyperglycemia is characterized by increase in infarct size and increased cerebral edema (both cytotoxic and

vasogenic) and hemorrhagic transformation in focal brain ischemia seizures [30].

18.3.1 Diagnostic Criteria for Hyperglycemia

The basic diagnostic criterion for hyperglycemia is elevation in the blood glucose level. However, the cutoff for diagnosis of hyperglycemia in the ICU and perioperative period is very much varied and complicated by various factors. This is due to the differences in the management strategies adapted by different institutions. Moreover, the diagnostic criteria of hyperglycemia are often confused values used for diagnosis of diabetes mellitus (DM), and the values are even extrapolated. Admission hyperglycemia or its complications like ketoacidosis may occur in acute neurological patients who are previously euglycemic or undiagnosed DM or patients with documented DM. Moreover, the criteria specific for use in pediatric patients is not established.

The normal fetal mean blood glucose is approximately 3 mmol/L, and immediately after birth there is transient neonatal hypoglycemia due to the limited capacity of newborns to produce endogenous glucose. It was found that by 72 h after birth, the capacity to generate endogenous glucose improves, and the blood glucose level reaches a higher level comparable to the children and adult level which is maintained within a narrow range of 3.5–5.5 mmol/L due to interactions of various hormones [31].

The recent guidelines issued by the American Diabetes Association (ADA) for diagnosis of DM are (1) fasting plasma glucose (FPG) > 126 mg% (7.0 mmol/L) or 2-h postprandial plasma glucose (PG) > 200 mg% (11.1 mmol/L) or glycosylated hemoglobin (A1C) of more than 6.5% or patients with classical symptoms of diabetes or diabetic ketoacidosis with random plasma glucose >200 mg%. A *prediabetic state (impaired glucose tolerance)* is also described and defined with FPG levels between 100 mg% (5.6 mmol/L) to 125 mg% (6.9 mmol/L) or 2-h PG 140–199 mg% (7.8–11 mmol/L) or A1C between 5.7 and 6.4% [32].

The diagnosis of hospital-related hyperglycemia is not clear. Dungan et al. have proposed for diagnosis of hospital-related hyperglycemia in patients without previous history of DM to be fasting glucose >6·9 mmol/L or random glucose >11·1 mmol/L without evidence of previous diabetes. In patients with preexisting poorly controlled diabetes, deterioration of pre-illness glycemic control with elevated plasma glucose (>30 mg% from preexisting values or >200 mg%) is usually considered for diagnosis of the condition. In a well-controlled diabetic patient with A1C < 7%, the above criteria used for nondiabetic patients would suffice [33].

In addition to hyperglycemia, it is important to understand the criteria for hypoglycemia as aggressive treatment of hyperglycemia can result in reduced plasma glucose [32]. Hypoglycemia is defined as three levels: (a) hypoglycemia alert (PG < 70 mg%, 3.9 mmol/L), (b) clinically significant hypoglycemia (PG <54 mg%, 3.0 mmol /L), and (c) severe hypoglycemia with cognitive decline needing external assistance (PG values undefined).

18.3.2 Management of Hyperglycemia in Hospitalized Patients

Hyperglycemia in acute illness cannot be preventable; however high degree of anticipation, early recognition, and management of the condition can help in improving patient's outcome and reduced hospital stay. In patients with neurological illness with preexisting DM, A1C levels will help in understanding the control of glucose. The targets for control as suggested by American Diabetes Association (ADA) would help in reducing the perioperative as well as ICU complications. The ADA recommends A1C of <7.0%, fasting plasma glucose of 80–130 mg%, and postprandial plasma glucose of <180 mg% as targets for glycemic control in nonpregnant adult diabetic patients [34]. In pediatric patients and young adults with known DM, the recommended targets for glycemic control are A1C <7.5%, fasting PG 90–130 mg%, and postprandial PG 90–150 mg% [35].

The treatment targets and strategies for hospitalized especially ICU patients presenting with hyperglycemia without history of DM are very challenging.

1. The hyperglycemia may be transient, usually seen at time of presentation in the emergency department or in the first 24 h of admission to ICU especially in acute cases after which the glucose levels return to baseline.
2. The difficulty in differentiating SH from patients who have impaired glucose tolerance or undiagnosed DM may interfere in the short-term vs long-term management of the metabolic problem. The levels of A1C may give a clue about the type of hyperglycemia. Patients with diabetes ketoacidosis and hyperosmolar coma may present clinically with acute neurological problems and needs to be managed as per the protocols existing for the treatment of the condition [36].
3. Perhaps the most important is the different type of protocol followed in the management of hyperglycemia. Three methods are available for management of the condition, namely, tight control, liberal control, and conventional method, with each of them having the advantages and disadvantages. Hence it is difficult to give a recommendation for hyperglycemia management.

   Since hyperglycemia was associated with increased mortality, *tight control* of plasma glucose was thought to reduce mortality and was advocated in many ICU settings. However, studies analyzing the effects of tight control on outcomes showed conflicting results. A large randomized study NICE-SUGAR (Normoglycemia in Intensive Care Evaluation-Survival Using Glucose Algorithm Regulation) evaluated tight control of sugar (80–120 mg%, 4.5–6 mmol/dL) using intense insulin therapy vs conventional regime where plasma glucose was targeted 180 mg% (10 mmol/dL) or less in patients admitted to critical care units. The study investigators found that tight control of glucose resulted in more mortality compared to conventional regime [37]. A subgroup analysis of patients with TBI in NICE-SUGAR study has shown that high incidence of moderate and severe hypoglycemia was seen in tight control group even though mortality was not different thereby questioning the practice of tight control of glucose [38]. The curve plotting mortality vs glucose level is found to be U-shaped with increased mortality seen if glucose level exceeds >200 mg% and if it falls below 80 mg%. Given the high risk of hypoglycemia between 80–110 mg%, it would be beneficial to maintain the glucose level between 110 and 180 mg% in patient admitted to critical care unit [39].
4. In a recent guideline issued by the American College of Physicians, a more liberal target glucose level of *140–200 mg%* (7.8–11.1 mmol/dL) has been advised in patients with hyperglycemia requiring insulin therapy regardless of presence of diabetes or not [40]. A large retrospective study analyzed different levels of plasma glucose (tight blood glucose (4.4 < 6.1 mmol/l), moderate (6.1 < 7.8 mmol/l), mild (7.8 < 10.0 mmol/l), and very mild (10.0 to <12.2 mmol/l) in over 17,996 patients on the mortality benefits [41]. The study found that mild glycemic control (7.8 to <10.0 mmol/l) achieved the best outcome in relation to all-cause mortality and hypoglycemia which was recommended by the ADA [42].
5. In patients with TBI, recent Brain Trauma Foundation (BTF) guidelines (fourth edition) mentions that "it is not clear whether aggressive therapy is better than conventional glucose control. For this reason, the evidence was rated as insufficient and no recommendation about glucose control can be made at this time" [43].

18.4 Perioperative Hyperglycemia Management

The perioperative management of patients with hyperglycemia is even more complex as the condition is caused or aggravated by multiple factors like stress; severity of disease; surgical and anesthetic techniques; use of drugs that interfere

with action of endogenous insulin like steroids, catecholamines, etc.; different intravenous fluids administered; and the nutritional management of patient. No specific targets for control are available in patients undergoing neurosurgery though it is well known that intraoperative hyperglycemia worsens outcome [44]. Perioperative hyperglycemia is associated with increased risk of infection, pneumonia, and acute renal failure in different studies [45, 46].

The recommendations for intraoperative blood glucose (BG) management are not very clear compared to ICU and non-ICU settings. The Society for Ambulatory Anesthesia (SAMBA) recommends intraoperative BG levels to be maintained less than 180 mg% (10 mmol/dL) and to start subcutaneous insulin if it exceeds 180 mg% [47]. Though literature exists on perioperative glucose management in general and cardiac surgical population, there are limited resources available for neurosurgical patients. A similar approach in management of hyperglycemia as in elective general surgery can be applied in neurosurgery population till appropriate literature is available. The perioperative management has significantly changed over the years due to different classes of drugs available currently.

18.4.1 Preoperative Period

A thorough preoperative evaluation of patient is needed before elective surgery to rule out SH from DM as well as presence or absence of macrovascular and microvascular complications of DM. The perioperative glucose management differs from type 1, type 2 DM, and stress hyperglycemia. In a known patient with DM, a thorough knowledge of preoperative medications, and adequacy of control based on preoperative A1C and blood glucose levels of DM, is needed. Elective surgeries can be postponed till adequate control of blood glucose levels is achieved. A preoperative diabetic enteric diet containing low-carbohydrate high monounsaturated fatty acid has been shown to reduce postprandial sugars by 18–29 mg%. Prolonged fasting must be avoided in diabetic patients. In patients on insulin, sensitivity must be established based on the formula; insulin sensitivity factor is equal to 1800/the patient's total daily dose (TDD) of insulin or 40 (in patients with oral agents or details not available). Patients requiring >80 IU per day, high body mass index, on large dose of prednisolone (>20 mg/day), are considered insulin resistant.

18.4.2 Management of Diabetics with Preexisting Drugs

Patients with type 1 diabetes must receive insulin subcutaneous injection which is 80% of their basal dose in the previous day evening and in morning on the day of surgery to avoid hyperglycemia. Prandial insulin must be omitted. Among the class of oral hypoglycemic drugs in type 2 diabetic patients, metformin, thiazolidinediones, DPP-4(dipeptidyl peptidase-4) inhibitors can be given in the preoperative period and on the day of surgery for short duration surgeries. If the surgery is long (>4 h) then these drugs must be withheld on the day of surgery. If patient is on sodium-glucose cotransporter 2 inhibitor therapy, the drugs may cause diabetic ketoacidosis and need to be stopped 24 h before surgery, and alternate drugs or insulin needs to be started for BG control. In type 2 diabetic patients on insulin, basal dose of insulin (glargine or detemir) must be reduced to 75% on the previous evening and morning on the day of surgery. Patients on neutral protamine Hagedorn (NPH) or intermediate and long-acting insulin dose must be reduced to 50–70% of usual dose on the previous day, and the morning dose must be preferably withheld on the day of surgery in prolonged surgeries. If BG is less than 120 mg% in the morning on the day of surgery, insulin and oral antidiabetic drugs can be omitted for the risk of hypoglycemia [48].

18.4.3 Intraoperative Management

Intraoperatively insulin can be administered either as continuous infusion or subcutaneous boluses. In minimally invasive surgeries, short

duration surgeries (<4 h), and patients with hemodynamic stability, subcutaneous insulin (short acting) can be administered. In other cases, intravenous continuous short-acting insulin is preferred. Subcutaneous insulin is equally effective and avoids the fluctuation in glucose levels and prevents hypoglycemia than bolus doses of insulin. Two hourly BG must be monitored in subcutaneous route, and hourly monitoring is needed if infusion is chosen for correction. However, the subcutaneous dose should not be repeated within 2 h to avoid overdose. The dose of subcutaneous insulin required can be calculated as (measured glucose—100/insulin sensitivity factor). A rough estimate would be to administer 2–3 IU of insulin if BG > 180–220 mg% and to increase the dose by 1–2 IU for every 40 mg% increase in BG above 220 mg% [49].

Intravenous infusion of rapidly acting insulin (half-life 15 min) can be started at rate determined (blood glucose/100 = IU/h) to target a BG of 140–180 mg%. The infusion can be maintained at same rate if target levels are achieved. For every 40 mg% increase, infusion can be stepped up by 1 IU/h. If it falls below 110 mg%, the infusion can be stopped and hourly BG must be monitored. The infusion can be continued in the postoperative period with same targets in ICU till patient is stabilized. In stable postoperative patients, subcutaneous insulin can be considered till the patients are given the adequate oral intake of calories after which they can be given usual preoperative regime they were on. Follow-up of patients with impaired glucose tolerance and stress hyperglycemia is required as 60% of them have been found to develop diabetes within a year [50].

18.4.4 Specific Considerations for Neurosurgery Patients

1. Patients with DM known to have high incidence of cardiovascular disease and autonomic dysfunction. Since neurosurgical procedures are conducted in different positions like head elevation, sitting, etc., risk of cardiovascular adverse events including collapse can occur during positioning as well as in the maintenance phase. Perioperative cardiovascular events can complicate the surgical procedure.
2. Glucose-containing fluids (5% Dextrose) are avoided in neurosurgery due to risk of hypotonicity and cerebral edema. Aggressive management of hyperglycemia with insulin in this situation can cause hypoglycemia.
3. Uncontrolled hyperglycemia can cause hyperosmolarity, diuresis, electrolyte imbalances, and reduced intravascular volume. DM can worsen the cerebral edema due to cytotoxicity and disrupted BBB causing intraoperative brain bulge. Use of aggressive hyperosmolar therapy for treating brain edema in such situation can rapidly increase the serum osmolarity and renal dysfunction.
4. Patients with DM may have altered renal function. Radiological investigative procedures like CT scan and angiography requiring contrast can worsen the renal dysfunction.
5. Patients with longstanding DM can have cognitive dysfunction and can interfere in perioperative anesthetic management and neurological assessment.
6. Regional anesthesia techniques and total intravenous anesthesia have been shown to provide better glucose control compared to general anesthesia. Use of volatile agents inhibits insulin secretion and increases hepatic glucose production and worsens hyperglycemia [51]. Capillary blood samples are unreliable in the ICU and should never be used.

18.4.5 Hyperglycemia Management in Acromegaly and Cushing's Disease

Management of hyperglycemia is very challenging in patients with hypersecreting hormones like acromegaly and Cushing's disease due to the fact that the condition is caused by endogenous resistance to insulin secreted by pancreas rather than deficiency of insulin per se. In many of these patients, it may not be possible to achieve a good glucose control in preoperative period before surgery. The hyperglycemic state may revert to

normal after removal of hypersecreting tumor if the patient did not develop overt DM. Since corticosteroids antagonize insulin action, fasting BG may be normal, but postprandial BG may be more than 200 mg%.

Recently the Italian Society for the Study of Diabetes (SID)/Italian Endocrinological Society (SIE) had issued guidelines for the management of hyperglycemia in these subsets of patients [52]. Patients with acromegaly can be treated with medical management, radiotherapy, or surgery. Patients can present to surgery with preoperative medications for the treatment of the condition and may have implications. Medical management of patients with acromegaly includes dopaminergic agonist (bromocriptine, cabergoline), somatostatin agonist (SSA) (octreotide, pasireotide, lanreotide), and pegvisomant, a genetically engineered GH receptor antagonist. Among these agents, treatment with SSA has been shown to worsen the hyperglycemia, whereas other agents tend to improve the glycemic status. No literature exists on the type of drugs that can be used to control hyperglycemia in acromegaly. Treatment with metformin alone or in combination with other drugs like pioglitazone tends to improve sensitivity to insulin and can be effective. If it fails, insulin can be used to control the blood glucose.

In patients with Cushing's syndrome, drugs used in medical management like ketoconazole, metyrapone, and mifepristone have been found to improve glucose levels. In corticosteroid-induced hyperglycemia, the steroid drugs must be given at the lowest required doses. Insulin sensitivity can be improved by oral antidiabetic drugs like metformin, sulphonyl urea, glinides, glitazones, and gliptins. In patients not controlled by the above agents, insulin can be considered. The insulin can be given as bolus or basal-bolus technique. Since the hyperglycemia is postprandial type, bolus of short-acting insulin can be given subcutaneously in the prandial period. The main disadvantage of only bolus is fluctuation in glucose levels. If bolus doses do not achieve adequate control, a basal dose of intermediate-acting insulin subcutaneous route along with postprandial short-acting insulin will provide a good control.

Perioperative hyperglycemia can be managed as per institutional protocol as well as guidelines based on elective surgical patients. It must be remembered that following successful surgery, there can be risk of steep fall in blood sugar with risk of hypoglycemia due to fall in hormonal levels, especially if the patient is on long-acting oral antidiabetic drugs or insulin. Hourly or 2-hourly sugar level monitoring is essential in the postoperative period for immediate identification of its onset.

18.5 Conclusion

Hyperglycemia has been shown to be one of the important causes of secondary brain damage and poor outcome in patients with neurological and neurosurgical conditions. Appropriate management of the condition has shown to have favorable outcomes in terms of infections, mortality, and reduced hospital stay. A protocol-based management with specific targets based on available literature and guidelines, as well as team approach, will facilitate achieving the goals of treatment. Follow-up of patients is required for incidental detected hyperglycemia to identify overt DM development, to provide antidiabetic therapy and prevent late complications.

Key Points

- Hyperglycemia is very common in various neurological and neurosurgical conditions with incidence ranging from 30 to 70%.
- Hyperglycemia worsens the outcome in various neurological diseases.
- Diagnostic criteria for perioperative hyperglycemia are not well established; criteria used by the American Diabetes Associations for the diagnosis of diabetes mellitus are often used.
- A more liberal target glucose levels of 140–200 mg% (7.8–11.1 mmol/dL) have been advised in patients with hyperglycemia requiring insulin therapy regardless of presence of diabetes or not.

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