White Paper

Using a Computerized Glucose Management System in the Cardiovascular Intensive Care Unit

Samuel "Ned" Crockett, MD, FACP, FACE, CDE
Former Medical Director of the Diabetes Institute,
Florida Hospital
Endocrinologist/Diabetologist
Consultant to Adventist Health System
Hyperglycemia Initiative

Dr Crockett's distinguished career is highlighted by his work in clinical research, medical education, and clinical practice. He has been affiliated with Florida Hospital Orlando since 1982, where he served as Medical Director and Director of Clinical Research of the Diabetes Institute for 15 years. He has received honors for his teaching, served on the editorial boards of professional publications, and held numerous posts in the American Association of Clinical Endocrinologists and the American Diabetes Association. For the past eleven years, Florida Hospital has been named by *U.S. News & World Report* as one of the Top Fifty Diabetes Centers in the United States. Dr Crockett has been instrumental in achieving good, targeted glucose control in Florida Hospital ICUs.

Introduction

Managing glucose levels in a cardiovascular intensive care unit is a demanding process complicated by the critical and complex nature of the patient who often presents with numerous comorbid conditions. The volatility of glucose concentrations in the critically ill cardiovascular patient requires significant resources for monitoring and treatment.

Poor in-hospital glycemic control is an ever-present issue.[1] Both persistent hyperglycemia and hypoglycemia increase the risk of adverse events and in-hospital morbidity and mortality,[2] and they create a major safety issue. Many attempts have been made to improve glycemic control in the ICU, including the creation of new protocols, training approaches, and computer algorithms.[3] This paper discusses the implementation of a computerized glucose management system in a cardiovascular intensive care unit at Florida Hospital Orlando, a 1,432-bed tertiary care hospital.

Challenges of Glucose Control in Critically Ill Patients

Hyperglycemia. Hyperglycemia (blood glucose levels >200 mg/dL[2,4]) is associated with increased morbidity and mortality in critically ill patients, whether the patient has previously diagnosed diabetes or has elevated glucose levels secondary to acute illness or trauma. Hyperglycemia in hospitalized, non-diabetic patients may be caused by a number of mechanisms, including metabolic stress during critical illness, parenteral nutrition, or drug therapies such as glucocorticoids.[5] It is associated with problems of tissue and organ perfusion, wound healing, increased infection,[6,7] and exacerbation of macro- and microvascular complications.

Evaluation of the effects of persistent hyperglycemia in a clinical study of trauma patients showed that high (>220 mg/dL) glucose levels and worsening or highly variable glucose control were most predictive of increased ventilator days, hospital and ICU lengths of stay, infection and mortality.[8] It has also been demonstrated in a hospital-wide population that the mortality rate among those with newly diagnosed hyperglycemia (on-admission or in-hospital fasting glucose levels 126 mg/dL, or random glucose levels >200 mg/dL) was significantly higher (16%) than among patients with a prior history of diabetes (3%) or those with normal glucose levels (1.7%). The newly diagnosed hyperglycemia patients were also more likely to be admitted to the ICU and have a longer length of hospital stay.[4]

Paul R. Garrett, Jr, MD
Medical Director Evidence-Based Practice
Office of Clinical Effectiveness
Adventist Health System

During the 18 years that Dr Garrett was in private practice in hematology/oncology at Florida Hospital Orlando, he served in several medical staff leadership positions, ultimately as President of the Medical Staff where he oversaw more than 1,500 physicians. He was involved in developing Florida Hospital's Cancer Center, which sees more new cancer patients annually than any other cancer center in Florida, and he also served as Medical Director of Hospice of Central Florida for three years. After leaving private practice, Dr Garrett was named Chief Medical Officer of Florida Hospital, and Senior Medical Director of Florida Hospital Healthcare System. He has headed several community projects and assisted in writing *Supersized Kids*, one of the first books to address the pediatric obesity epidemic. Dr Garrett currently is the Medical Director of Evidence-Based Practice for the 37-hospital Adventist Health System.

"In the cardiovascular surgery ICU, the utilization of glucose management software has resulted in improved glucose control and a significant reduction in hypoglycemia that we could not attain with our paper protocol."

— S. Crockett, MD, FACP, FACE, CDE

Hypoglycemia. Severe hypoglycemia (blood glucose levels <40 mg/dL[9]) can result in a significant increase in morbidity and mortality. It is a primary limiting factor in achieving optimal glycemic control,[10] and is an important factor in recent discussions regarding tight glycemic control (TGC) and intensive insulin therapy.[11]

Careful monitoring and treatment can avoid the risk of hypoglycemia in hospitalized patients.[10] Better nurse education and training on the uses of new technology, e.g., computerized insulin-dosing algorithms,[12] as well as adherence to practice guidelines, can also help.[13]

Glucose fluctuations. It is clear that both hyper- and hypoglycemia put patients at risk. However, acute glucose variations are also a problem.[14] Glucose variability has been shown to increase hospital morbidity and mortality.[15-17] A significant relationship between acute glucose swings and activation of oxidative stress has been demonstrated in patients with type 2 diabetes. This relationship was not observed in patients with chronic sustained hyperglycemia.[14] Oxidative stress may trigger complications, such as vascular damage, in diabetic patients.[14] Critically ill patients, whose glucose levels fluctuate due to the stress of their illness, medication, or surgery, may be at increased risk for morbidity or mortality.[15-17]

Cardiovascular patients. Most patients who experience an acute coronary event have abnormal glucose metabolism.[18] A study of 127 non-diabetic patients in intensive care following an acute coronary event showed that only 23% (29 patients) had normal glucose.[16,18] The others had newly diagnosed type 2 diabetes, impaired glucose tolerance, or isolated impaired fasting glucose. Hyperglycemia on admission following an acute myocardial infarction is also associated with increased risk of mortality.[2] The excessive stress response induced by cardiac surgery in non-diabetic patients, especially cardiopulmonary bypass surgery, can result in hyperglycemia, which may be an early signal of an increased risk for developing diabetes in the future.[19]

Glucose control with EndoTool®

Keeping glucose levels in balance can help reduce morbidity and mortality, but can be challenging for healthcare providers. EndoTool is a highly sophisticated software system designed to customize IV insulin dosing to the individual patient, even those with rapidly changing insulin requirements. The computer-driven software uses mathematical models to identify trends in a patient's response to IV insulin. These data are analyzed to formulate a patient-specific physiologic insulin dosing curve.

Lori Hadas, MSN, RN, CCRN-CSC
Cardiovascular Nurse Specialist
Department of Cardiothoracic Surgery
Florida Hospital Orlando

Lori Hadas has been affiliated with Florida Hospital for 22 years, with 12 years in the Cardiovascular Intensive Care Unit (CVICU), where she works with cardiac surgical patients. She has led the glycemic control initiative for the cardiac surgical patients and developed hyperglycemia protocols for the CVICU and the Cardiothoracic Operating Room (OR). She is a member of the Diabetes Collaborative Practice Committee, Medication Safety Committee, and Pharmacy and Therapeutics Committee, and she serves as a clinical advisor for the rollout of the EndoTool software system in all of the ICUs at the seven campuses in the Florida Hospital System.

Darcey Harnage, RN, BSN
Senior Project Manager
Critical Care Services
Florida Hospital Orlando

Darcey Harnage has been a bedside nurse for 21 years, focusing primarily on Intensive Care Unit (ICU), Emergency Department (ED), and quality and safety issues. As Senior Project Manager for Critical Care Services, she is responsible for projects in Florida Hospital Orlando's 11 intensive care units, which have a total of 136 ICU beds. She is a member of several hospital committees that address critical care issues, and serves as the chair for the System Rapid Response Team Committee. Darcey has received Six Sigma Greenbelt certification, a program designed to enhance problem-solving skills in order to improve organizational processes. She is responsible for the implementation of the EndoTool software system for glycemic control in all 11 of the hospital's ICUs.

"Glucose management software has stabilized the process by which patients receive insulin infusions while significantly reducing hypoglycemic events."

— D.L. Harnage, RN, BSN

When the caregiver enters a patient's current glucose level, the curve is automatically adjusted to help minimize or prevent extremes in glucose levels. EndoTool has been shown to help achieve target blood glucose levels quickly—within an average of 5 to 6 hours.[20] It has also been shown to be more effective than paper-based protocols in maintaining glucose levels in the goal range.[21] Incidence of hypoglycemia with EndoTool has been shown to be <0.05% of readings.[20]

Implementation of EndoTool by Florida Hospital

The Florida Hospital, part of the Adventist Health System, is an 7-campus system with locations throughout Central Florida. The flagship institution is Florida Hospital Orlando, an acute care tertiary facility. More patient visits—1.5 million—are conducted here annually than in any other hospital in the country. With its international reputation for superior care, Florida Hospital Orlando is home to more than 1,000 physicians and 5 intensive care units, including a 28-bed cardiovascular intensive care unit (CVICU).

EndoTool implementation at Florida Hospital was begun as an Adventist Health System Corporate initiative in December 2007. This was prompted by a desire to decrease the risk of hypoglycemia/hyperglycemia in critically ill patients in the hospital, and to achieve consistency in glycemic management throughout the system. Until this initiative, glycemic control was maintained with intravenous insulin defined by paper protocols. Paper protocols can be complicated, subject to individual nurse interpretation, and have no proactive alarms. The data are not reviewable without doing patient chart reviews. Compliance with the paper protocols was a problem, limiting its value; there was also wide variation in physician practice related to transitioning off an insulin infusion. Factors like these helped determine that a better system was needed.

Planning and training. A system-level team was established to approve milestones and deliverables. Each hospital also created a multidisciplinary team led by a physician champion and an RN liaison. Other members included dietary, pharmacy, education, and IT personnel. The team identified potential barriers to the implementation, as well as needs for education. EndoTool resource people (super users) helped with the implementation and with clinical support.

Nurse training was mandatory and consisted of class time (about 1.5 hours), which included hands-on use of the software supervised by the EndoTool clinical team members. Classes were conducted by vendor specialists. Because of the number of ICU personnel in the hospital, additional classes with greater flexibility were required, including early

Jean Turcotte, MA, RN, CCRN-CSC
Administrative Nurse Manager CVICU
Florida Hospital Orlando

Jean Turcotte has been affiliated with the Florida Hospital Cardiovascular Institute for the past 15 years as a staff nurse and currently as the Administrative Nurse Manager of the CVICU. He has a passion for clinical advancement and excellence, and as a participant on the CV Governance Council he acts as a resource to the leadership team in supporting new initiatives that help clinicians achieve positive patient experiences and outcomes. Jean has been instrumental in the implementation and success of the EndoTool software system in the CVICU.

"Glucose management software provides the only approved protocol for insulin therapy in the ICU."

— D.L. Harnage, RN, BSN

morning and late evening sessions. These classes were supported by Florida Hospital personnel.

Florida Hospital began implementation in one of its campuses in July 2008 and completed it on all 7 campuses, including Florida Hospital Orlando, by October 2008.

About CVICU. As a tertiary center, the CVICU at Florida Hospital Orlando is large (28 beds) and treats very ill patients. The population is older and many have diabetes (see the Capsule Summary). Current practice is to monitor all intensive care patients with EndoTool who meet the following criteria: Diagnosed diabetic patients with one blood sugar reading

Florida Hospital Orlando CVICU

Capsule Summary, 2008 data

- 1,326 cardiac surgery procedures
- 770 isolated CABG procedures
- 426 valve or valve with CABG procedures
- CABG and valve procedures, Patient profiles
  - Average age, 65 years
  - 28% COPD
  - 22% Smoking history
  - 40% Diabetic
  - 83% Dyslipidemia
  - 42% Family History of CAD
  - 19% History of CV Disease
  - 84% Hypertension
  - 9% Renal Insufficiency
  - 2% Renal Failure- Dialysis
  - 7% Prior CABG surgery
  - 3% Prior Valve surgery
- Infection rates
  - Overall surgical site—2.2%
  - Deep sternal—1.2%
  - Superficial sternal—0.9%
  - Deep donor site—0.0%
  - Superficial donor site—0.09%

>150 mg/dL and non-diagnosed diabetic patients with two readings >150 mg/dL. The data in the Capsule Summary (see page 4) demonstrate the impact of glucose management while using EndoTool in this challenging patient population.

"With glucose management software, we have better controlled blood sugars."

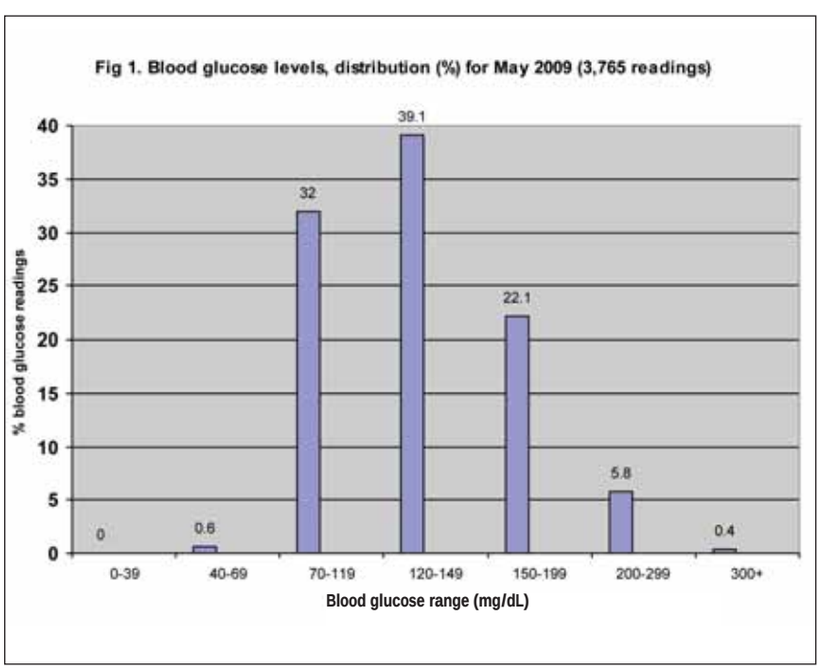
– J. Turcotte, MA, RN, CCRN-CSC

Results with EndoTool

After six months of experience with EndoTool, the CVICU at Florida Hospital Orlando has had impressive results. The glucose targets for this unit were set to a range of 100 mg/dL to 150 mg/dL. Subsequently, on April 3, 2009, based on the nursing staff's increasing comfort with the software and on the excellent results, the upper blood glucose target was lowered to 140 mg/dL. (The criteria for triggering use of insulin infusion via EndoTool, described earlier, remains the same.) The change in parameters was done to improve blood glucose averages, achieve better control, and decrease the time to control.

Recent data are shown below. Other results are being compiled and analyzed and will be reported at a later date.

- Of 3,462 glucose readings for the month of April 2009 (110 patients), none showed hypoglycemia (<40 mg/dL). This was also true in May 2009, with no incidents of hypoglycemia in 3,765 glucose readings (106 patients)
- In April, 68.6% of the readings were between 70 mg/dL and 149 mg/dL; 71.1% were within this range in May (Fig 1.)



- After 4 hours of treatment average glucose level was 133 mg/dL in April and 132 mg/dL in May
- The average time to achieve control was 4.1 to 4.4 hours for the two months
- The percentage* of glucose readings showing hypoglycemia (glucose levels ≤40 mg/dL) decreased from 0.52% to 0.12% from May 2008 to March 2009. EndoTool was implemented on October 11, 2008, in the CVICU

*RALS data based on Accu-Chek® readings, with or without EndoTool

Implementation of EndoTool required the support and energy of a hospital-wide team. Initial concerns included increased nursing time required for IV insulin infusions, since all intensive care patients who meet the required criteria are now routinely put on an IV insulin infusion. And though paper protocols for transitioning off an insulin drip were in place prior to EndoTool, they were not well understood or followed. The EndoTool transition orders were easier to follow and are customized to the individual patient.

The CVICU nursing staff was already familiar with titrating insulin infusions to an ordered blood glucose range; however, titration practices varied, which led to inconsistent control of blood glucose levels. When EndoTool was implemented, many nurses were skeptical about accepting computer-generated instructions and increased dosing amounts, and were not accustomed to providing IV insulin boluses along with the hourly rate adjustments. However, with careful monitoring, nursing staff became comfortable with the larger dosing and boluses prescribed by EndoTool and realized the practice was safe and resulted in few incidents of hypoglycemia.

The successful implementation of EndoTool depended not only on the nurses' knowledge of the pathophysiology and benefits of glycemic control in the cardiac surgical patient population; it also required an environment of sup-

port. The nurse manager budgeted for nurse technicians to help with the frequent bedside glucose measurements, and also negotiated to have one bedside glucose meter for every two patients. Nursing leadership also monitored compliance with the CMS (Centers for Medicare & Medicaid Services) requirement of maintaining glucose levels below 200 mg/dL at 6 am on postoperative days 1 and 2.[22] The cardiovascular clinical nurse specialist and unit education specialist also played integral roles in providing clinical support and real-time instruction and troubleshooting of complex patient scenarios.

Conclusion

The importance of excellent glucose control in critically ill cardiovascular patients cannot be overstated. EndoTool has played an important part in helping this busy CVICU maintain good glucose control in a large population of very ill surgical patients. The incidence of hypoglycemia, a significant concern in managing glucose levels, decreased in the CVICU to zero in both April and May of this year and the majority of glucose readings were between 70 mg/dL and 149 mg/dL for these two months. Though initial acceptance met with some skepticism, physicians and nurses have found EndoTool to be an invaluable asset in maintaining glucose control with a low incidence of hypoglycemia in the CVICU.

"The use of glucose management software for IV insulin infusion management provides a safe and effective means of achieving good, targeted glucose control in the ICU setting without significant episodes of hypoglycemia." [from press release]

— S. Crockett, MD, FACP, FACE, CDE

References

1. Wexler DJ, Meigs JB, Cagliero E, Nathan DM, Grant RW. Prevalence of hyper- and hypoglycemia among inpatients with diabetes. *Diabetes Care.* 2007;30(2):367-369.

2. Kosiborod M, Inzucchi SE, Krumholz HM, et al. Glucometrics in patients hospitalized with acute myocardial infarction: defining the optimal outcomes-based measure of risk. *Circulation.* 2008;117:1018-1027.

3. Van den Heuvel I, Elliger B. A sweet debate: glycemic control in the intensive care unit. *Crit Care Med* [letter]. 2008;36(12):3271-3272.

4. Umpierrez GE, Isaacs SD, Bazargan N, et al. Hyperglycemia: an independent marker of in-hospital mortality in patients with undiagnosed diabetes. *J Clin Endocrinol Metab.* 2002 Mar;87(3):978-82.

5. Campbell RK. Etiology and effect on outcomes of hyperglycemia in hospitalized patients. *Am J Health-Syst Pharm.* 2007;64(suppl6):S4-S8.

6. Campbell RK. Improving glycemic control in hospital patients with and without diabetes mellitus. *Am J Health-Syst Pharm.* 2007;64(suppl6):S3.

7. Dungan KM, Braithwaite SS, Preiser JC. Stress hyperglycemia. *Lancet.* 2009;373:1798-1807.

8. Bochicchio GV, Sung J, Joshi M, et al. Persistent hyperglycemia is predictive of outcome in critically ill trauma patients. *J Trauma.* 2005 May;58(5):921-924.

9. Van den Berghe G, Wilmer A, Hermans G, et al. Intensive insulin therapy in the medical ICU. *N Engl J Med.* 2006;354(5):449-461.

10. Hassan E. Hyperglycemia management in the hospital setting. *Am J Health-Syst Pharm.* 2007;64(suppl6):S9-S14.

11. NICE-SUGAR Study Investigators. Intensive versus conventional glucose control in critically ill patients. *N Engl J Med.* 2009;360(13):1283-1297.

12. Mechanick JI. Hypoglycemia in the intensive care unit. *Curr Opin Clin Nutr Metab Care.* 2007;10(2):193-196.

13. Anthony M. Treatment of hypoglycemia in hospitalized adults: a descriptive study. *Diabetes Educ.* 2007;33(4):709-715.

14. Monnier L, Mas E, Ginet C, et al. Activation of oxidative stress by acute glucose fluctuations compared with sustained chronic hyperglycemia in patients with type 2 diabetes. *JAMA.* 2009;295(14):1681-1687.

15. Ali NA, O'Brien Jr JM, Dungan K, et al. Glucose variability and mortality in patients with sepsis. *Crit Care Med.* 2008;36:2316-2321.

16. Krinsley JS. Glycemic variability: a strong independent predictor of mortality in critically ill patients. *Crit Care Med.* 2008;36:3008-3013.

17. Egi M, Bellomo R, Stachowski E, et al. Variability of blood glucose concentration and short-term mortality in critically ill patients. *Anesthesiology.* 2006;105:244-252.

18. Ilany J, Marai I, Cohen O, et al. Glucose homeostasis abnormalities in cardiac intensive care unit patients. *Acta Diabetol.* 2008 Nov 21. Available at www.ncbi.nlm.nih.gov. Accessed April 4, 2009.

19. Gornik J, Vujaklija A, Lukic E, et al. Hyperglycemia in critical illness is a risk factor for later development of type II diabetes mellitus. *Acta Diabetol.* 2009 Apr 2. Available at www.ncbi.nlm.nih.gov. Accessed April 4, 2009.

20. Data on file. Incidence of hypoglycemia (≤40 mg/dL). Goal range was set to 85-120 mg/dL. Hospira Inc.

21. Saager L, Collins GL, Burnside B, et al. A randomized study in diabetic patients undergoing cardiac surgery comparing computer-guided glucose management with a standard sliding scale protocol. *J Cardiothorac Vasc Anesth.* 2008;22:377-382.

22. Centers for Medicare & Medicaid Services (CMS), The Joint Commission. Surgical care improvement project: percent of cardiac surgery patients with controlled 6 A.M. postoperative blood glucose. Oct 2008. Available at: http://www.qualitymeasures.ahrq.gov/summary/word.aspx?doc_id=13233&stat=1&string=. Accessed: June 1, 2009.

Case Study 1:

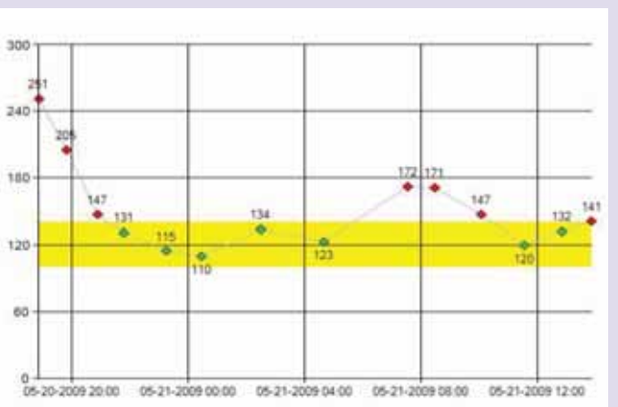
Mr. H, a 78-year-old male, was admitted to the CVICU for an aortic dissection. He has a history of diet-controlled diabetes, and was put on steroid therapy to manage chronic obstructive pulmonary disease (COPD). He takes no glycemic-control medications.

On admission, his weight was 84 kg, he had a serum creatinine level of 1.6 mg/dL, and his hemoglobin A1c level was 7.5% (HbA1c <6% is normal). EndoTool monitoring was initiated after ascending aortic aneurysm repair, which concluded without incident.

He remained intubated on postoperative day 1, and total parenteral nutrition (TPN) was ordered. Immediately postoperatively, blood glucose levels were above 265 mg/dL and were under control within 4.5 hours of surgery. On days 2 and 3, his glucose levels were maintained between 100 mg/dL and 140 mg/dL, but spiked to 240 mg/dL on day 4. This may have been due to the fact that Mr. H was now extubated and starting to take an oral diet. By day 5 and continuing through day 8, Mr. H's glucose levels were stable below 150 mg/dL on subcutaneous insulin therapy. He was discharged to a rehabilitation facility for gait training and short-term assistance before being released to home.

Case Study 2:

Ms. M is a 77-year-old woman admitted to the CVICU for mitral valve replacement. She has no history of diabetes. Past medical history includes previous triple bypass surgery, gastrointestinal reflux disease (GERD), and permanent pacemaker insertion.



Initial examination revealed an HbA1c of 5.7% (HbA1c <6% is normal). Her creatinine level was 1.1 mg/dL and her weight was 82 kg. EndoTool monitoring was initiated after mitral valve repair surgery with an annuloplasty ring.

Immediately postoperatively, Ms. M's glucose levels spiked to 251 mg/dL and then decreased to <150 mg/dL within two hours of surgery. She was extubated four hours after surgery and started on a clear liquid diet. Glucose levels remained below 150 mg/dL until postoperative day 1, when it fluctuated to 147 mg/dL and 172 mg/dL due to extra dextrose given via electrolyte replacement after diuresis, and diet advancement to full liquids. She tolerated a no concentrated sweets (NCS) diet by the morning of postoperative day 3. Ms. M was transitioned off the insulin infusion and placed on the subcutaneous correction dose with prandial short-acting insulin that was calculated by the EndoTool software. She was transferred to the cardiovascular step-down unit and discharged to home on postoperative day 6.

Case Study 3:

Mr. W is a 63-year-old male, status post-cardiac arrest, following an acute anterior wall myocardial infarction. He was admitted to CVICU for emergency triple coronary artery bypass graft (CABG). He was diagnosed with type 2 diabetes five years ago, which was treated at home with metformin. Other medications include lisinopril, carvedilol, and aspirin.

On admission, his HbA1c was 8.5%. In the immediate postoperative period, Mr. W was on multiple inotropic and vasoactive medications from which he was gradually weaned. On postoperative day 2, Mr. W was started on total parenteral nutrition (TPN). His glucose was managed with EndoTool for six days postoperatively.

Initially, his glucose level was 190 mg/dL, but it gradually decreased to between 100 and 120 mg/dL within four hours of surgery. His glucose levels remained relatively stable within range (100 mg/dL to 140 mg/dL) until day 4, when a feeding tube was placed and postpyloric enteral feedings were initiated. His glucose levels rose to above 160 mg/dL but were quickly stabilized on EndoTool. EndoTool was discontinued on postoperative day 5 and Mr. W. was transitioned to long-acting subcutaneous insulin with a correction scale dosing of short-acting insulin every six hours. Mr. W was subsequently extubated and transferred to the progressive care floor where he was discharged home with home health care support and physical therapy.

For more information on Advancing Wellness™, contact your Hospira representative at **1-877-946-7747** or visit **www.hospira.com**

Hospira

Advancing Wellness™

P09-2170