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Original Article

Review of Insulin Therapy and Pen Use in Hospitalized Patients

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Abstract

Objective: Hyperglycemia is common among hospitalized patients, affecting approximately 40% of patients at the time of hospital admission, despite the fact that 1 in every 8 patients has no previous diagnosis of diabetes. Hyperglycemia has been associated with poor patient outcomes, including higher rates of morbidity and mortality across a range of conditions. This review discusses options for the effective management of hyperglycemia with a focus on the use of disposable insulin pens in the hospital.

Methods: Literature, including guidelines for hospital management of hyperglycemia, and information regarding methods of insulin administration were reviewed.

Results: Appropriate glucose control via administration of insulin within hospitals has been acknowledged as an important goal and is consistent with achieving patient safety. Insulin may be administered subcutaneously using a pen or vial and syringe or infused intravenously. Levels of patient and provider satisfaction are higher with pen administration than with vial and syringe. Insulin pens have many safety and convenience features including enhanced dose accuracy and autocover/autoshield pen needles.

Conclusion: Use of insulin pens instead of vials and syringes can provide several advantages for hospitalized patients, including greater satisfaction among them and health care providers, improved safety, and reduced costs. These advantages can continue following patient discharge.

Key Words—diabetes mellitus, hyperglycemia, hospital, insulin pens

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The total cost of diabetes in the United States has been estimated as $174 billion in 2007.[1] The largest component (50%) of overall costs related to diabetes care is attributed expenditures from hospital inpatient care. Approximately one-fourth of all hospital inpatient days are incurred by patients with diabetes. The prevalence of diabetes among hospitalized patients has been conservatively estimated in 12% to 26% of adult patients.[2] The etiologies of hyperglycemia in hospitalized patients are numerous and can be broadly classified as preexisting diabetes, undiagnosed diabetes, and transient hyperglycemia related to stress of illness, fluids/nutrition, or medications.[3] A study of 2,030 adult patients found that hyperglycemia was present in 38% of patients at the time of hospital admission, where 12%, or 1 of every 8 patients, had no prior diagnosis of diabetes.[4] Newly discovered hyperglycemia was associated with increased mortality, longer hospital length of stay, and higher rates of intensive care unit (ICU) admission, and patients were less likely to be discharged to home, which resulted in a greater need for transitional or nursing home care. Hyperglycemic patients are at risk for poor clinical outcomes compared to their normoglycemic counterparts both during their hospital stay and following discharge.[5]

Several studies have shown evidence that hyperglycemia is associated with an increased rate of wound

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infection and postoperative stroke, increased length of stay, and higher mortality in multiple patient populations across various acuities of care.[6-17] A large study with data from approximately 260,000 patients from 173 US medical, surgical, and cardiac ICUs found an association between hyperglycemia and mortality.[18] Patients with a mean blood glucose (BG) of 200 to 300 mg/dL (adjusted odds ratio [aOR] 2.13; 95% CI, 2.03-2.25) and greater than 300 mg/dL (aOR 2.85; 95% CI, 2.58-3.14) had 2 to 3 times the odds of mortality compared to normoglycemic patients (BG 70-110 mg/dL).

These findings underscore the need to optimize glucose management in hospitalized patients. Early studies evaluated the use of intensive insulin therapy in critically ill patients.[11,19,20] An early landmark study by Van den Berghe and colleagues[20] in 2001 found a significant reduction in mortality by 42% when using intensive insulin therapy targeting BG values between 80 to 110 mg/dL compared to conventional therapy targeting BG values between 180 to 200 mg/dL. Additionally, they found significant reductions in the incidence of septicemia, and patients were less likely to require prolonged mechanical ventilation and intensive care.

In 2004, the American Association of Clinical Endocrinologists (AACE) published the first glycemic targets and the American Diabetes Association (ADA) first published recommendations for inpatient glycemic care in its yearly standards of care, which until then had focused solely on outpatient care.[3]

Although intensive insulin therapy has been shown to enhance utilization of health care resources, as represented by reductions in the cost of intensive care[21] and improved outcomes across a variety of settings,[20,22,23] results from several clinical trials have been conflicting.[24-31] A more recent landmark study, the Normoglycemic in Intensive Care Evaluation and Survival Using Glucose Algorithm Regulation (NICE-SUGAR) trial, randomized 6,104 critically ill patients to a regimen of intensive glucose control, with a target BG range of 81 to 108 mg/dL, or conventional glucose control, with a target of less than 180 mg/dL.[26] The primary endpoint of the study was all-cause mortality within 90 days after randomization. The study found no mortality benefit in attempting to achieve the intensive BG target range. The conventional glucose control group had lower mortality than the intensive glucose control group (24.9% vs 27.5%; OR for intensive control, 1.14; 95% CI, 1.02-1.28; $P = .02$). Patients in the intensive glucose control group also experienced significantly more hypoglycemic episodes than the conventional group (13.7% vs 2.5%; relative risk [RR] 5.13; 95% CI, 4.09-6.43). It was noted that in the NICE-SUGAR trial, most patients required insulin to achieve even less stringent glucose targets.

Confusion regarding specific glycemic targets and means for achieving them in both critically and noncritically ill patients led the AACE and ADA to convene and develop an updated joint consensus statement on inpatient glycemic management. The goal was to establish reasonable, achievable, and safe glycemic targets and describe protocols, procedures, and system improvements to facilitate their implementation.[25]

This review will discuss the current recommendations for the management of hyperglycemia in hospitalized patients and the impact of insulin pen devices in this setting.

GUIDELINES FOR INSULIN THERAPY IN THE HOSPITAL

The AACE and ADA consensus statement on inpatient glycemic control defines hyperglycemia as any BG greater than 140 mg/dL, hypoglycemia as any BG less than 70 mg/dL, and severe hypoglycemia as any BG less than 40 mg/dL.[25] The AACE and ADA examined available literature and developed glycemic targets to balance treating hyperglycemia while avoiding hypoglycemia. If BG levels persistently exceed a threshold of 180 mg/dL, the majority of critically ill patients should have an insulin infusion to control hyperglycemia and maintain a BG range of 140-180 mg/dL (**Table 1**). A target BG less than

Table 1. Target blood glucose (BG) concentrations in hospitalized patients[25]

Patient type	Target BG, mg/dL	BG when modification of insulin regimen may be necessary, mg/dL	Recommended insulin route
Critically ill in intensive care settings	140-180	<110: Not recommended	Intravenous
Not critically ill	Premeal: <140 Random: <180	<100: Reassess regimen <70: Modify regimen	Subcutaneous (scheduled)

110 mg/dL is not recommended, however lower glucose targets may be appropriate in selected patients. It is highly recommended that institutions use standardized insulin infusion protocols with validated efficacy and minimal rates of hypoglycemia that include diligent glucose monitoring and dosage adjustments.[25,32]

For the majority of noncritically ill patients, the AACE/ADA consensus statement recommends premeal BG targets less than 140 mg/dL with random levels less than 180 mg/dL (**Table 1**).[25,32] The glycemic targets for noncritically ill patients are based primarily on clinical experience, because prospective, randomized, controlled data in this population are lacking. Consideration should be given for BG levels less than 100 mg/dL to avoid hypoglycemia and modification of the regimen may be necessary for BG less than 70 mg/dL. Glycemic control in noncritically ill patients with sustained hyperglycemia should be managed using scheduled subcutaneous insulin consisting of a basal, nutritional, and supplemental (correction) components.[25,32]

Management of inpatient hyperglycemia is complicated by frequent changes in nutritional status (ie, nothing by mouth, enteral tube feeding), medications, changes in patient clinical status, and poor coordination of BG testing with prandial insulin administration. These complexities, when considered in combination with poor outcomes associated with hypo- and hyperglycemia and cost-effectiveness of glycemic control, create a strong argument for a multidisciplinary approach and institutionwide protocols for glycemic control.

The American Society of Health-System Pharmacists (ASHP) guidelines for safe use of insulin in hospitals recommend a multidisciplinary team approach. These guidelines recommend that institutions develop standardized procedures for BG management to improve patient outcomes. These should include protocols for continuous insulin infusions, patients undergoing high-risk transitions of insulin therapy, or conversion from infusion to intermittent subcutaneous administration.[33] In addition, the ASHP guidelines state that patients and providers should receive education to enhance patient management and provider safety when administering insulin. Despite these recommendations, a survey conducted in 2009 involving 47 hospitals found that only 39% had implemented inpatient diabetes and hyperglycemia quality improvement programs for critically ill patients, only 21% for the noncritically ill, and only 15% for perioperative patients.[34]

OPTIMIZING INSULIN ADMINISTRATION IN THE HOSPITAL

There are a variety of insulins and insulin analogs available to manage hyperglycemia and maintain target BG levels (**Table 2**).[35] There are several regimens used to administer insulin in hospitalized patients, however there are no universally established insulin infusion protocols or subcutaneous regimens

Table 2. Insulin pharmacokinetic profiles[35]

Insulin type	Onset[a]	Peak[a]	DOA[a]
Rapid-acting analogs			
Lispro	5-15 min	30-90 min	4-6 h
Aspart	5-15 min	30-90 min	4-6 h
Glulisine	20 min	100 min	5 h
Short-acting			
Regular[b]	30-60 min	2-3 h	8-10 h
Intermediate-acting			
NPH	2-4 h	4-10 h	12-18 h
Long-acting analogs			
Glargine[c]	2-4 h	No pronounced peak	Up to 24 h
Detemir[c]	2-4 h	Relatively flat[d]	Up to 24 h[d]

Note: DOA = duration of action; NPH = neutral protamine Hagedorn. Reprinted, with permission, from Kelly JL. Ensuring optimal insulin utilization in the hospital setting: role of the pharmacist. *Am J Health Syst Pharm*. 2010;67(16 suppl 8):S9-16. Copyright © 2010 by American Society of Health-System Pharmacists, Inc.
[a]Estimates only. Effects in individual patients vary.
[b]Based on subcutaneous administration.
[c]Cannot be mixed with any other insulin; requires a separate injection.
[d]Varies by dose; higher dose, longer duration.

that have been validated in large, prospective studies. Although no one specific intravenous (IV) or subcutaneous protocol is recommended for use by the AACE/ADA consensus statement, they support the use of protocol-driven IV infusions in critically ill patients with hyperglycemia and scheduled subcutaneous insulin for achieving and maintaining glucose control in noncritically ill patients with diabetes or stress hyperglycemia.[25]

IV insulin infusion requires frequent, labor-intensive monitoring and documentation. Consequently, many hospitals have adopted policies stating IV insulin infusions may only be administered at the ICU level of care. Under these circumstances, continuous insulin infusion serves as a barrier to transferring patients outside the ICU.[36] Therefore, conversion from a continuous IV insulin infusion to a subcutaneous insulin regimen is an important step in transitioning patients to lower intensity care, and it is also appropriate when they begin eating regular meals.[2,25] Conversion from IV to subcutaneous insulin can place the patient at an increased risk for a hyper- or hypoglycemic event, therefore proper transition to subcutaneous dosing should be managed appropriately to maintain adequate glucose control.

Because the pharmacokinetic properties of insulin differ between analogs and between IV and subcutaneous administration (**Table 2**), the transition from IV infusion to subcutaneous insulin should be overlapped to achieve effective blood levels of insulin. Short- or rapid-acting subcutaneous insulin should be administered 1 to 2 hours before discontinuation of the IV insulin infusion while intermediate or long-acting insulin should be injected 2 to 3 hours before discontinuing the infusion to allow for subcutaneous insulin to take effect and reduce the risk of significant hyperglycemia during the transition period.[5] Transitioning from an insulin infusion to subcutaneous can be calculated from the insulin infusion rate. The AACE/ADA consensus statement suggests using a percentage (usually 75% to 80%) of the total daily IV infusion dose, which is then proportionally divided into basal and prandial components.[25] Another method described in the literature is to calculate the daily insulin requirement from the insulin infusion rate and the amount of dextrose the patient is receiving. If the patient is not eating and is receiving no more than 120 g of dextrose daily, then the insulin infusion is primarily providing basal needs. Thus, the daily subcutaneous dose can be estimated as 60% to 80% of the calculated daily insulin requirement and given as basal insulin. If the patient is receiving at least half of their estimated caloric needs, then the insulin infusion is providing both basal and prandial coverage. Therefore, the patient should receive 30% to 40% of the calculated daily insulin requirement as basal and 30% to 40% as prandial insulin.[35]

Insulins available for subcutaneous administration include human insulin formulations (regular insulin and neutral protamine Hagedorn [NPH]) and insulin analogs (lispro, aspart, glulisine, detemir, glargine) (**Table 2**). Both long- and rapid-acting analogs are associated with a more consistent pharmacokinetic and pharmacodynamic profile with less inter- and intra-individual variability.[2] The AACE/ADA statement recommends insulin analogs for managing hyperglycemia in hospitalized patients with type 2 diabetes.[25] The preferred method for delivery of subcutaneous insulin therapy should be comprised of 3 components: basal (daily or twice-daily injections of long-acting insulin), prandial or nutritional (injections of rapid-acting insulin before meals), and correction insulin.[25]

Rapid-acting analogs are effective for controlling postprandial BG. Dosing should be adjusted based on the changing nutritional intake of the patient.[37] Rapid-acting insulin analogs should be provided immediately prior to a meal. Alternatively, a rapid-acting insulin analog may be administered immediately after a meal and can be tailored based on the amount of food the patient has consumed.[37] Regular human insulin should ideally be given 30 minutes before meals, a goal that may be difficult to meet in hospitals where meal delivery cannot always be accurately predicted.[37]

Sliding scale insulin (SSI) administration, referring to the practice of insulin administration only when the patient is out of range, is considered an ineffective practice.[25] Traditional SSI administration involves measurement of BG prior to each insulin dose, but it cannot be used by itself to keep blood sugar levels consistently within the target range.[38] Patients treated with SSI are managed reactively, without appropriate basal insulin dosing.[37] A retrospective chart review study of 391 hospitalized patients with pneumonia documented a 2.6 times higher risk of a composite outcome (inhospital mortality, sepsis, ICU admission, or cardiovascular complications) with SSI administration compared with patients not managed using SSI administration ($P < .0001$).[39] In addition, average glucose values were higher in the SSI group (213.2 mg/dL vs 129.7 mg/dL; $P < .0001$). The only study to evaluate the effectiveness of SSI compared to individualized doses of scheduled insulin and as-needed correction insulin was the Randomized Study of Basal

Bolus Insulin Therapy in the Inpatient Management of Patients with Type 2 Diabetes (RABBIT 2) trial.[40] This was a prospective, randomized study in non-ICU patients with type 2 diabetes comparing a basal-bolus regimen of insulin glargine and glulisine (n = 65) versus a standard SSI regimen using regular insulin (n = 65). Patients randomized to the basal-bolus regimen received 0.4 units/kg/day when admission BG was between 140 and 200 mg/dL or 0.5 units/kg/day when admission BG was between 201 and 400 mg/dL. Half of the total daily dose of insulin was provided as insulin glargine and the other half was provided as insulin glulisine in 3 equally divided doses administered before each meal. Supplemental correction insulin glulisine was given following the sliding scale protocol for BG greater than 140 mg/dL. Patients randomized to the SSI protocol were only given regular insulin based on BG levels greater than 140 mg/dL according to classification of the patient as insulin sensitive, usual, or insulin resistant. Supplemental doses of insulin glulisine were added to the scheduled premeal insulin if BG was greater than 140 mg/dL. In this study, BG target less than 140 mg/dL was achieved by a higher percentage of patients in the basal-bolus group compared with the SSI group (66% vs 38%), with no observed increase in the frequency of hypoglycemia. SSI regimens fail to provide adequate glycemic control and are not recommended in the management of hospitalized patients.[25,40]

The AACE/ADA consensus statement concurs that SSI is consistently overused for management of hyperglycemia and prolonged therapy with SSI as the sole regimen is ineffective in the majority of patients.[25] Instead of SSI, they recommend use of "correction insulin," or additional short- or rapid-acting insulin, in conjunction with scheduled insulin doses to address BG levels that are above desired targets.

USE OF INSULIN PENS IN ADMINISTERING SUBCUTANEOUS INSULIN

Diabetes progression can be associated with visual loss, and elderly patients may have decreased manual dexterity, which can cause additional difficulties when administering insulin.[41] Drawing up insulin and administration of doses in either the outpatient or inpatient setting can be difficult and requires proper technique and training for patients and health care providers. Subcutaneous insulin may be administered by either a vial and syringe or an insulin pen. Some insulin pens offer visual and audible cues to support dosing accuracy, thereby reducing the risk of medication errors. This may be an important consideration among patients with type 2 diabetes who have not previously been treated with insulin. However, counting clicks in order to select the dose is not recommended. Several disposable insulin pens are available for use in the hospital for subcutaneous administration (**Table 3**).[41]

Health Care Provider Satisfaction

The use of insulin pens has been associated with higher health care provider satisfaction compared with vial and syringe administration, mainly due to enhanced convenience and controlled dosing.

Table 3. Disposable insulin pen devices available in the United States[41]

Name	Manufacturer	Insulin
FlexPen	Novo Nordisk A/S	• Insulin detemir • Insulin aspart • Insulin aspart mix (70% insulin aspart protamine suspension/30% insulin aspart)
KwikPen	Eli Lilly and Company	• Insulin lispro • Insulin lispro mix (75% insulin lispro protamine/25% insulin lispro) • Insulin lispro mix (50% insulin lispro protamine/50% insulin lispro)
Lilly pen	Eli Lilly and Company	• Insulin lispro • Insulin lispro mix (75% insulin lispro protamine/25% insulin lispro) • Insulin lispro mix (50% insulin lispro protamine/50% insulin lispro) • Human insulin isophane suspension (NPH) • Premixed human insulin (70% NPH/30% regular human insulin)
SoloSTAR	sanofi-aventis	• Insulin glargine • Insulin glulisine

Note: NPH = neutral protamine Hagedorn.
Adapted, with permission, from Goldstein HH. Pen devices to improve patient adherence with insulin therapy in type 2 diabetes. *Postgrad Med*. 2008;120:175. Copyright © 2008 by JTE Multimedia.

Compared with vial and syringe administration, the pen offers advantages in the hospital and as a part of a transition plan for patients who must remain on insulin following discharge.[42,43] A quasi-experimental, 1-group, posttest-only study of 54 nurses in a community hospital showed that after implementation of insulin pen devices, nurses were more satisfied with insulin pens compared with vials and syringes.[42] The majority of nurses surveyed agreed that insulin pens were more convenient (80% agreed), required less time to prepare and administer insulin (70%), and were an improvement over vials and syringes (69%). Specifically, the nurses appreciated the fact that implementation of these insulin pen devices was not found to increase nursing time spent to teach patients to self-inject insulin and was not associated with an increase in insulin-related needlestick injuries.[42]

Provider and patient satisfaction with pen devices has been demonstrated across care settings. Physician satisfaction was evaluated after implementation of pen devices in 33 ambulatory clinics over a 6-week period. Almost all of the physicians felt more confident in patients' ability to accurately deliver a dose, believed it required less time to train patients, and noted that it was easier to initiate insulin for insulin-naïve patients with pen devices than with vials and syringes.[44] This finding has been consistent across several provider satisfaction studies.[45-49]

Patient Acceptance

Studies have demonstrated that pen devices are associated with greater patient acceptance. A recent systematic review by Molife and colleagues[50] examined 29 outpatient studies that assessed patient preference as a primary outcome. In 28 of these trials, more than 66% of patients either preferred insulin pen devices or chose to continue treatment with insulin pens instead of vials and syringes. Another study of 94 hospitalized patients found that significantly more patients receiving insulin via an insulin pen were more likely to continue using such a device after discharge than those in the vial and syringe group ($P < .05$).[43] After discharge, more patients in the insulin pen group had insurance coverage for their insulin and related supplies compared to the vial and syringe group (79% vs 52%, $P = .070$). These findings are consistent with the increased likelihood of continuation of insulin pen use after discharge from the hospital.

Safety

Needlestick injuries are a major concern for health care workers. An average of 385,000 needlestick injuries occur annually in US hospital settings.[51] Up to 25% of needlestick injuries occur when recapping a used needle. The National Institute for Occupational Safety and Health (NIOSH) describes desirable safety features for devices associated with needlestick injuries. Some of the characteristics that apply to insulin administration include that the safety feature should be an integral part of the device and work passively, requiring no activation by the user. If user activation is necessary, the safety feature can be engaged with single-handed technique, allowing the worker's hands to remain behind the exposed needle. Other desired safety features include the following: the user can tell if the safety feature has been activated, it cannot be deactivated, and it remains protective through disposal.[52] Typical subcutaneous administration of insulin using traditional insulin safety syringes meets NIOSH requirements, however the safety feature is not optimal because it requires activation by the nurse to engage or "slide" the safety sheath into position to cover the exposed needle. Of the numerous safety syringes available, only 2 provide an automatic retractable needle, thus meeting all optimal NIOSH safety features for devices.[53] Despite the availability of an automatic safety feature on insulin syringes, many hospitals that do not use disposable insulin pens continue to use insulin safety syringes that require the user to actively engage the safety feature, leading to the potential for needlestick injuries.

Introduction of injection pens into the hospital setting without the use of proper safety features for the pen needles was associated with increased needlestick injuries to health care workers. A retrospective study conducted between October 1999 to September 2000 in 24 French public hospitals showed the use of injection pens was associated with 6 times more needlestick injuries than syringes (23.5 compared 3.85 needlestick injuries per 100,000 devices ordered, $P < .001$).[54] However, it is important to note that the authors stated that no safety needles were available at the time of the study and the injection pens were used by people other than trained health care workers on medical and diabetes-endocrinology specialty floors. Therefore, 60% of the 144 injuries were associated with disassembly of nonshielded pen needles and 55% of the needlestick injuries occurred on floors where untrained, nonspecialized health care providers worked. This study revealed the need for safety-engineered injection pen needles to improve health care worker safety and the importance of staff training to reduce the risk of needlestick injuries.[51]

Currently, use of nonshielded injection pen needles is not allowed in US hospital settings where the

patients do not self-administer insulin. The only insulin pen needles available for use in hospital settings have an integrated safety needle that uses a passive, automatic safety cover or shield to prevent the risk of a needlestick injury to the user. The 2 autocover/autoshield insulin pen needles available for use in the hospital are the *NovoFine Autocover* (Novo Nordisk Inc, Princeton, NJ) and the *BD AutoShield* (Becton, Dickinson and Company, Franklin Lakes, NJ). The autocover/autoshield covers the needle before injection, retracts during injection, slides back into place after injection to cover the needle again, and locks permanently into a shielding position following insulin delivery to protect the worker throughout the entire preparation and administration process.[55]

This important introduction of an automatic safety pen needle for use with disposable insulin pens and their impact on needlestick injury has only been prospectively evaluated in one study.[56]

The authors sought to determine the impact of switching from conventional insulin vials and syringes to disposable insulin pens on needlestick injuries and overall insulin costs. Patient and employee incident reports were reviewed to identify insulin-related staff needlestick injuries and other patient safety indicators 6 months prior and 6 months after the hospitalwide interchange. Over 4,000 patients were treated with insulin during the time period. There was an 80% reduction in the incidence of needlestick injuries after implementation of insulin pens (5 needlesticks/ 2,118 patients in the preimplementation phase vs 1 needlestick/2,084 patients in the postimplementation phase).[52]

Appropriate training for health care workers on administration technique is another key component to reducing needlestick injuries.[52] Previous studies describe utilization of competency-based training for nursing and pharmacy staff prior to implementation of hospitalwide use of insulin pens to ensure proper storage, labeling, dispensing, administration, and disposal techniques for the pens and needles.[42,56]

Cost Advantages

Use of insulin pens can reduce insulin costs compared with vial and syringe administration. A study in over 4,000 patients published by Ward et al[56] evaluated hospitalwide implementation of insulin pens and found a reduction in total cost of insulin products from $124,181 to $60,655 during the 6-month postimplementation period. The number of dosage units purchased was lower in the postimplementation period compared to the preimplementation period (4,356 vials vs 4,031 vials and pens), and the authors attribute the primary cost reduction to the switch from vials of long-acting insulin products to the insulin detemir pen. Previously, Davis et al[43] showed the costs of insulin vials, pens, syringes, and safety needles per patient were significantly higher in the pen group compared with those of the vial and syringe group ($154.39 compared to $108.04, respectively; $P = .012$). However, once the insulin direct costs per patient were adjusted to project dispensing only the equivalent insulin pen products, the average direct cost per patient for the pen group was projected to be $71.85, yielding a cost-saving of $36 per patient for the insulin pen group compared to the actual average total direct costs per patient in the vial and syringe group ($P = .006$). Eli Lilly and Company has recently added 3 mL rapid- and short-acting analog vials (*Humulin R*, *Humalog*; Eli Lilly and Company, Indianapolis, IN) for hospital use. The smaller size vial is less expensive than the traditional 10 mL vial and could be associated with less waste. Further studies need to be conducted to evaluate whether cost-savings would be achieved with the smaller size vial.

In a retrospective analysis of a matched-pair cohort from a Medicaid database, comparable medication adherence was observed for patients initiating insulin with a pen versus a syringe.[57] However, total annualized health care costs were significantly lower for patients using pen therapy than for those using a syringe ($14,857.42 vs $31,764.78, respectively; $P < .05$), resulting from lower hospital costs ($1,195.93 vs $4,965.31, respectively; $P < .05$), diabetes-related costs ($7,324.37 vs $13,762.21, respectively; $P < .05$), and outpatient costs ($7,795.98 vs $13,103.51, respectively; $P < .05$).[57] Additional analyses revealed costs of syringes were significantly lower ($535.70 vs $670.52, $P < .05$) and costs of pens were significantly higher ($840.33 vs $0, $P < .05$) among patients who were switched from syringes to pens. Patients who were converted from oral diabetes medications to pen therapy had significantly lower prescription costs than patients who used a vial/syringe ($6122.58 vs $7465.62, respectively; $P < .05$). Medicaid patients who were initiated on insulin pen therapy experienced fewer outpatient visits and hospitalizations. Two other published studies examining managed care claims data found that conversion from conventional insulin vial and syringe to insulin pen devices was associated with significant improvements in medication adherence, significant reductions in the likelihood of experiencing a hypoglycemic event, and significant reductions in hypoglycemia-related hospitalizations and outpatient physician visits.[58,59] Lee and

colleagues[58] studied 1,156 patients and found that these outcome improvements contributed to significant reductions in cost. In this study, the total mean all-cause annual treatment cost was reduced by $1,590 per patient ($16,359 to $14,769, $P < .01$) and annual diabetes-attributable health care costs were reduced by $600 per patient ($8,827 to $8,227, $P < .01$). Cobden and colleagues' study[59] of 486 patients found these outcome improvements contributed to significant reductions in the total mean all-cause annual treatment cost by $1,748 per patient ($16,004 to $14,256, $P < .01$) and other diabetes-attributable health care costs were reduced by $643 per patient ($8,669 to $8,056, $P < .01$).

CONCLUSION

As the prevalence of diabetes increases, strategies for optimizing glucose control within the hospital are becoming more and more important. Patients with hyperglycemia, with or without preexisting diabetes, have been shown to be at greater risk for poor outcomes, including higher rates of mortality, across a range of conditions. Practice guidelines emphasize the importance of achieving glycemic control and safety in hospitalized patients. Although IV insulin infusion may be used, administration of subcutaneous insulin is appropriate for a wide range of patient types. Modes of subcutaneous administration include vials and syringes, as well as pens.

Compared with vials and syringes, insulin pens can provide several advantages that are important to consider. In both the ambulatory and hospital setting, patients and health care providers prefer insulin pens over vials and syringes due to their greater convenience, safety features, and cost advantages. Other advantages of pens include features for enhancing dosing accuracy for patients and the potential for minimizing infection risk and improving patient adherence to insulin therapy.

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