Original Article

Patterns of Sharps Handling and Disposal Among Insulin-Using Patients With Diabetes Mellitus

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Jordan M. Montoya, BS[1], Bithika M. Thompson, MD[2], Mary E. Boyle, APRN, FNP-BC, MSN[2], Melinda E. Leighton, RN, CDE[3], and Curtiss B. Cook, MD[2]

Abstract

Background: The objective of this study was to assess disposal patterns for "sharps" among a cohort of patients with diabetes mellitus (DM) receiving insulin therapy.

Method: A convenience sample of inpatients and outpatients was surveyed about how they disposed of sharps, how often they reused lancets and needles, and what education they had received about proper disposal. *Safe* disposal was defined as discarding sharps into a formal sharps or sealable container; otherwise, disposal was categorized as *unsafe*.

Results: Of 150 respondents, 56% were men and 75% were white. The mean (SD) age was 56 (15) years; duration of DM, 20 (13) years; and hemoglobin A_{1c}, 8.1% (2.0%). Half the respondents reused a lancet two or more times, and 21% reused an insulin needle two or more times. Thirty-eight percent of respondents discarded lancets unsafely, and 33% discarded insulin needles unsafely, typically by throwing these items into household trash. Most respondents (75%) discarded insulin pens, vials, cartridges, insulin pump supplies, and continuous glucose monitor sensors into household trash. Most (64%) indicated that they had not received education on safe sharps-disposal practices, and 84% had never visited their municipal website for information on medical waste disposal.

Conclusion: Approximately one-third of patients unsafely disposed of sharps. Unsafe disposal could cause millions of sharps to appear in the municipal solid waste stream, thereby posing a substantial public health hazard. Point-of-care patient education is important, but a broader public health campaign may be required.

Keywords

diabetes mellitus, environmental, medical waste, safety, sharps

Introduction

Nearly 23 million people in the United States (7% of the population) are estimated to have a known diagnosis of diabetes mellitus (DM).[1] Maintaining optimal glycemic control often requires the patient to perform self-monitoring of blood glucose (SMBG), and nearly 29% of patients with DM are estimated to require insulin administration to control blood glucose levels.[2] Therefore, on the basis of these estimates, nearly seven million patients with DM in the United States could be receiving insulin therapy.

By definition, medical "sharps" include DM-related products, such as needles, syringes, lancets, insulin pens, infusion sets, and connecting needles and sets.[3] The last two are components of insulin pumps and continuous glucose monitors (CGMs). Self-monitoring of blood glucose and insulin administration require the use of lancets and needles. These sharps represent a form of medical waste that, unless properly discarded, could put an unsuspecting bystander at risk for direct contact with biologic materials via a needlestick injury.

The current data indicate that nearly eight billion injections occur outside of health care facilities annually.[3] The number of used needles discarded into household garbage nearly tripled from 2001 through 2011.[3] When disposed of improperly, needles present a risk to waste industry workers,

[1]Mayo Clinic Alix School of Medicine, Scottsdale, AZ, USA
[2]Mayo Clinic, Scottsdale, AZ, USA
[3]Mayo Clinic Hospital, Phoenix, AZ, USA

Corresponding Author:
Curtiss B. Cook, MD, Division of Endocrinology, Mayo Clinic, 13400 E Shea Blvd, Scottsdale, AZ 85259, USA.
Email: cook.curtiss@mayo.edu

especially those in facilities that sort recyclables and who may be in contact with sharps and blood-borne pathogens. A recent report estimated that as many as 1484 needlestick injuries occur every year at material recovery facilities, and these injuries result in $2.25 million in costs for treatment, prophylaxis, and monitoring.[3]

The epidemic of DM will likely increase the mass of DM-associated medical waste that includes sharps. Historically, most of the public health consequences of DM have been described in terms of complications and economic burden, but the environmental effects and public health risk posed by unsafe disposal of sharps generated through DM self-management have received little discussion. Disposal of loose needles into the municipal solid waste (MSW) stream is never considered acceptable.[3] The US Food and Drug Administration (FDA) recommends placing used needles and other sharps into a sharps-disposal container to reduce the risk of needlestick injuries. If an FDA-cleared container is not available for home use, a heavy-duty plastic household container has been suggested as an alternative. However, depending on the thickness of such containers, they may not be entirely safe either.[4,5] Additional guidelines are available from the US Environmental Protection Agency (EPA),[6,7] but regulations for sharps disposal may vary by state.[8] For instance, according to California state law, disposal of home-generated sharps waste in the trash or recycling containers is illegal, and all sharps waste must be transported to a collection center in a sharps container or other approved container.[8] The guidelines of the authors' home state follow FDA and EPA guidelines.[8,9]

Limited data from the United States and other countries have indicated that patients with DM unsafely dispose of their used sharps.[10-17] Given the increasing prevalence of DM, the increase in DM-related medical waste and its disposal needs further study. This must first start with a better understanding of the current disposal practices by patients and their educational needs regarding safe practices. Therefore, we conducted a survey to assess patterns of sharps use and disposal among a clinic- and hospital-based population of patients with DM receiving insulin therapy.

Methods

Survey Development

Few surveys about sharps-disposal practices of patients have been published, and our search of the literature did not identify a published questionnaire.[10-17] In addition, inpatients were not included in prior studies of medical waste-disposal practices, and we wanted to know whether their disposal practices differ from those of ambulatory patients. Additionally, prior studies did not include questions about insulin pump infusion sets and CGMs.[10-17] Therefore, questions about how patients dispose of these devices were also needed. We drafted a survey designed to gather data on patient self-reported practices about the use and disposal of sharps generated from conducting SMBG and administering insulin (Appendix). For the purposes of this study, we were interested in what patients were doing at home.

The survey included questions on how often respondents performed SMBG, how often they changed their lancets, and how they disposed of their lancets. The survey also included questions on insulin administration, such as how often patients injected insulin, how often they changed their needles, whether they recapped their needles, and how they disposed of their needles. Because glass vials and insulin cartridges (which are used in pen devices) are potentially recyclable, disposal methods for these items were assessed. The survey also distinguished between participants who used insulin pumps and CGMs and those who injected insulin and performed SMBG as their primary means of DM management. Finally, survey participants were asked whether they had received any education on safe sharps disposal and whether they had researched their municipal site for medical waste disposal.

Participant Recruitment

After receiving Mayo Clinic Institutional Review Board approval, we recruited a convenience sample of adult patients (age $\geq$18 years) with DM who were being seen as outpatients at an endocrinology clinic or as inpatients and receiving insulin treatment. Surveys were conducted from June 1, 2018, through October 31, 2018. Because the survey was written in English, only patients for whom English was their primary language were included. Surveys were completed by the patient, with assistance from study personnel when needed, and study personnel reviewed the surveys for completeness.

Data Analysis

Demographic characteristics and clinical information about DM were gathered with chart review and the survey. Data are expressed as number (percentage) or mean (SD). For the purposes of this analysis, a *safe* sharps-disposal practice was defined as placing the item in a sealable container (eg, a milk jug or formal sharps container). An *unsafe* sharps-disposal practice was defined as any other method of disposal (eg, throwing items directly into the garbage or flushing them down the toilet). Responses were analyzed separately for outpatients and inpatients. Differences were assessed with *t* tests for continuous variables or the χ^2 test for categorical variables.

Results

Participant Characteristics

The survey was completed by 150 patients, including 94 outpatients and 56 inpatients. The mean (SD) age of the entire cohort was 56 (15) years; self-reported DM duration, 20 (13)

Table 1. Survey Participant Characteristics ($N = 150$[a]).

Characteristic	Value[b]
Demographic	
Age, y	56 (15)
Men	84 (56)
White race/ethnicity	112 (75)
Clinical	
Diabetes duration, y	20 (13)
Hemoglobin A_{1c}, %	8.1 (2.0)
Body mass index, kg/m^2	30.4 (7.2)
Diabetes treatment	
Insulin injections only	92 (61)
Insulin injections and oral agents	27 (18)
Insulin pump	22 (15)
Insulin injections, noninsulin injectable, and oral agents	6 (4)
Insulin injections and noninsulin injectable	3 (2)
Method of glucose monitoring	($n = 147$[c])
Continuous glucose monitor	19 (13)
Self-monitoring of blood glucose	128 (87)

[a]Includes 94 outpatients and 56 inpatients. Differences between these groups of patients were not significant ($P \geq .09$ for all characteristics); therefore, only data on all participants are shown.
[b]Continuous variables are reported as mean (SD), and categorical variables are reported as *n* (%).
[c]Three respondents were excluded because they did not perform glucose monitoring at home.

years; hemoglobin A_{1c}, 8.1% (2.0%); and body mass index, 30.4 (7.2) kg/m^2 (Table 1). Most patients were men, and most were white. The most common treatment received was insulin injections only, followed by the use of insulin injections in combination with other therapies. Some participants were receiving insulin pump therapy. We observed no significant differences (all $P \geq .09$) in these characteristics between outpatient and inpatient respondents, so aggregate data are shown.

Few respondents used CGM devices rather than SMBG (Table 1), with no difference between the proportions of inpatient and outpatient respondents who used CGM ($P = .12$) or SMBG ($P = .15$). However, outpatients reported a slightly but significantly higher frequency of daily monitoring than inpatients (mean [SD], 4 [2] vs 3 [2] times per day; $P = .048$).

Patterns of Lancet and Insulin Needle Use

Respondents were asked how many times they used a lancet or insulin needle before it was discarded and replaced with a clean device. Three respondents reported that they did not perform glucose monitoring at home and were not included in the analysis of lancet use and disposal. Half of the respondents who performed SMBG indicated that they used a lancet only once, but a substantial proportion (42%) stated they used a lancet more than twice (Figure 1). Some outliers were noted. For instance, one respondent reported changing their lancet four times per year, another used a single lancet over 300 times, and a third changed lancets only once annually.

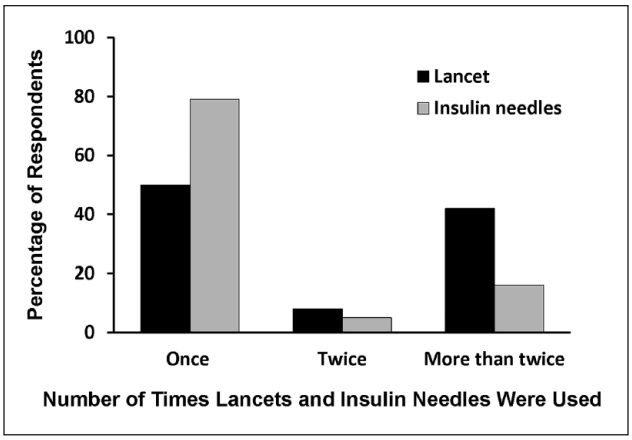

Figure 1. Number of times respondents reported using a single lancet or insulin needle.

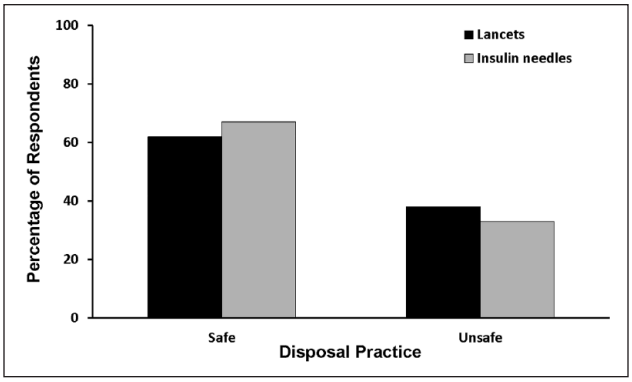

Figure 2. Lancet and insulin needle-disposal practices. *Safe* disposal was defined as discarding sharps into a standard sharps container or other sealable container; *unsafe* disposal was defined as any other method (eg, sharps were thrown into household trash).

Most respondents who injected insulin reported using insulin needles only once, and few used an insulin needle two or more times (Figure 1). One respondent used an insulin needle 40 times and another respondent used an insulin needle 90 times before disposal. We observed no differences in patterns of lancet or insulin needle use between outpatients and inpatients (all $P \geq .14$).

Patterns of Lancet and Insulin Needle Disposal

Among survey respondents who performed SMBG, more than 60% practiced safe disposal of their lancets (Figure 2). The other respondents typically threw their needles directly into their household garbage. One patient disposed of lancets

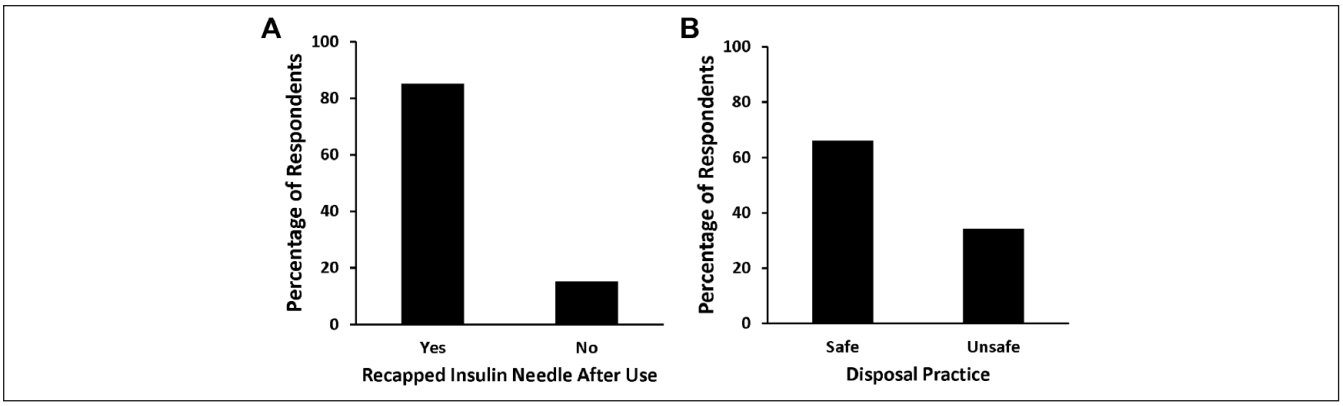

Figure 3. Disposal of recapped insulin needles. (a) Survey respondents who recapped their insulin needles after use. (b) Survey respondents who safely disposed of recapped needles. *Safe* disposal was defined as discarding sharps into a standard sharps container or other sealable container; *unsafe* disposal was defined as any other method (eg, sharps were thrown into household trash).

by flushing them down the toilet. Among respondents who injected insulin, two-thirds used safe disposal practices, but the other one-third placed their needles directly into the household garbage.

Patterns of disposal for lancets and insulin needles were comparable between inpatients and outpatients (all $P \geq .76$). In univariate analysis, lancet-disposal patterns did not vary according to respondent age, sex, hemoglobin A_{1c} level, body mass index, race/ethnicity, number of times lancets were used, or duration of DM (all $P \geq .08$). Insulin needle-disposal practices did not vary according to age, sex, hemoglobin A_{1c} level, body mass index, race/ethnicity, or number of times the insulin needles were used (all $P \geq .12$). However, insulin needle-disposal practices varied according to self-reported DM duration. Patients who disposed of needles in an unsafe manner had DM for a longer duration than those who used safe disposal patterns (mean [SD], 22 [12] vs 16 [12] years; $P = .03$).

Among the respondents who answered the survey question about recapping their insulin needles ($n = 124$), nearly all respondents indicated that they recapped their needle before disposal (Figure 3(a)). Among these 105 respondents who recapped their syringes, two-thirds disposed of their needles in a safe manner, and the other one-third discarded needles into the household garbage (Figure 3(b)). Thus, even though these respondents recapped the needle first, their insulin needle-disposal practices still did not meet the definition of safe sharps disposal.

Disposal of Other DM Products

Most respondents discarded glass insulin vials, insulin cartridges, and insulin pens directly into the garbage (Figure 4(a)). Similar practices were noted for disposal of used insulin pump supplies and CGM sensors (Figure 4(b) and (c)). When respondents described "other" means of disposal for these items, the most common method was to place them into a sharps container or an alternative sealable container, and this method was classified as *safe disposal*.

Education About Disposal Practices

The majority of the 150 respondents (96 [64%]) indicated that they had never received instruction about safe sharps disposal as a part of their education about DM management. In addition, most (130 [87%]) indicated that they had never visited their municipal website for medical waste disposal. Similar proportions of inpatients and outpatients reported not receiving education on proper sharps disposal ($P = .70$) and not having knowledge about their municipal website for medical waste disposal ($P = .22$).

Discussion

Household-generated sharps have been documented in MSW streams. Several factors, such as home management of increasingly prevalent medical conditions, confusion about proper sharps disposal, and lack of access to needle take-back programs, raise concern that the problem of needles and other sharps in MSW streams will only increase.[3] DM, which is epidemic and increasing in prevalence, is among the medical conditions likely to contribute to the increasing mass of sharps that could enter into the MSW stream.[1]

The previous studies from the United States and other countries have reported unsafe disposal practices for medical sharps among patients with DM, and patients report being poorly educated on the topic.[10-17] Unlike the previous reports, the current study included patients from inpatient and outpatient settings. We believed that the inclusion of inpatients was important because no data are available about their at-home disposal practices. We had no reason to assume that their processes would differ from those of ambulatory patients, and the analyses showed that their processes were similar. The findings of this study are similar to those of the

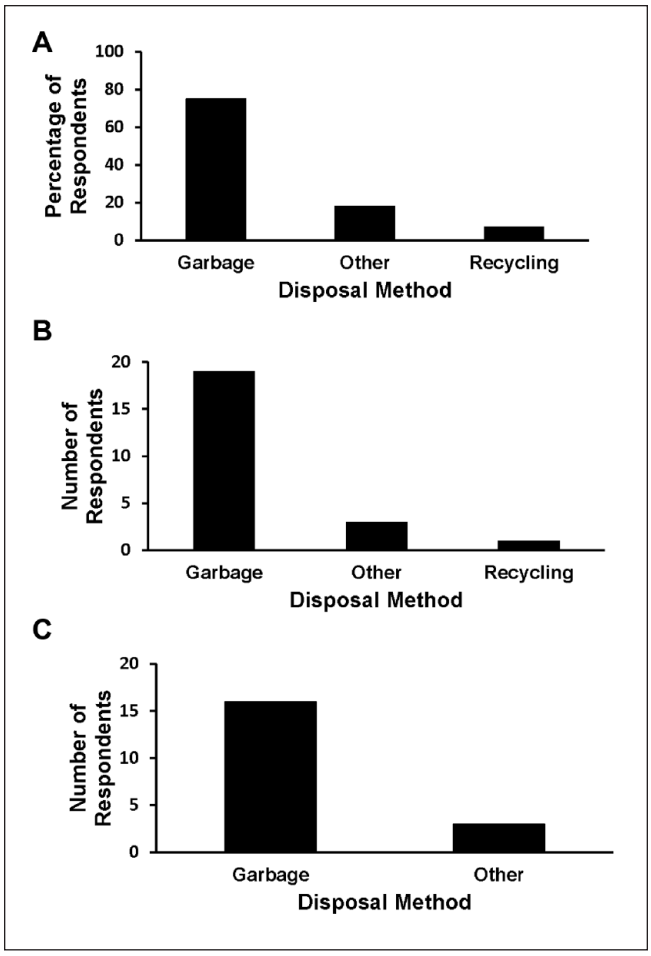

Figure 4. Disposal methods for various types of diabetes mellitus supplies. (a) Insulin pens, vials, and cartridges. (b) Insulin pump supplies (e.g. infusion sets). (c) Continuous glucose-monitoring sensors. Because of the small sample size, number rather than percentage is reported in panels (b) and (c). *Other* includes sharps containers and alternative sealable containers.

previous studies,[10-17] and this report is the most recent addition to the literature indicating that little has changed in the habits of patients with DM or their perceptions about the management of DM-associated waste. Overall, approximately one-third of respondents disposed of their lancets and insulin needles in an unsafe manner, and their disposal practices would not be considered in compliance with recommendations. Some respondents may have believed that recapping their insulin needles would make them sufficiently safe for disposal, but the needle and cap could separate, leaving an unprotected needle with its attendant risk if simply thrown into household trash. Moreover, few respondents indicated that they had received specific education about proper sharps-disposal practices.

Unlike other reports, this study also examined how patients disposed of CGM and insulin pump-related waste. Although such patients constituted only a small proportion of all respondents, CGM and insulin pump use are increasing, and how such medical waste is discarded by this subset of patients warrants further study. Most respondents discarded their CGM sensors and insulin pump waste directly into the household trash. Although clear guidelines exist for disposal and handling of household sharps,[4,6-8] the authors were unable to locate any federal or state guidelines about how to handle waste generated from the use of CGM sensors and insulin pumps. Review of guidelines from various vendors indicated that different recommendations are provided to patients about how to discard used sensors and infusion sets. For instance, one CGM manufacturer recommends placing used sensors in a sharps container,[18] but another vendor recommends discarding sensor-containing patches according to local guidelines.[19] Similarly, guidelines from insulin pump and patch manufacturers either state that patients should follow local guidelines for infusion set disposal or do not provide guidance.[20-22] However, if local guidelines do not exist, then patients using a CGM or insulin pump have no source of information to consult during decision making. Educating patients about proper disposal techniques is difficult because of the lack of consistent guidelines about handling CGM and insulin pump-generated waste.

Most patients discarded glass insulin vials, insulin cartridges, and disposable plastic insulin pens into the household trash rather than recycling them. For patients to recycle these medical-grade products, they would need to be composed of recyclable materials. Given their potentially recyclable glass and plastic composition, the reason why these items were not recycled is unclear but may be due to the presence of residual insulin product. Discharging pharmaceuticals into the environment is an ongoing concern.[23-25] Residual insulin in vials and cartridges may pose challenges to recycling facilities because the drug should be removed before recycling the container. *m*-Cresol, also known as meta-cresol and 3-methylphenol, is a methyl-substituted phenol and used as a preservative in insulin solutions. Waste can be classified as hazardous if it contains *m*-cresol at a concentration over the regulatory limit of 200 parts per million (ppm). The concentration of *m*-cresol in insulin solutions ranges from to 1700 to 3000 ppm, thereby exceeding the regulatory level for hazardous waste.[26] Moreover, in order to recycle vials and plastic insulin pens, these medical grade products would need to be composed of recyclable materials. As an alternative to recycling or disposal in household trash, used and unused insulin vials and cartridges can be delivered to local medical waste-collection centers.

We previously defined *geoenvironmental diabetology* as the study of how geophysical phenomena affect patients with DM, as well as metabolic control, DM equipment, medications, supplies, access to care, and the adaptive strategies implemented by patients to manage their DM under extreme scenarios (eg, floods, hurricanes, heat waves, and war).[27] The definition could be expanded to include the effects of DM

waste on the environment. Full assessment of these effects requires evaluation of important questions, such as how much DM waste is generated, what products are used, how much (eg, weight and volume) of these products are used, and how these products can be recycled. For example, a recent study suggested that insulin pumps contain little recyclable materials.[28]

This study has several limitations but provides opportunities to expand surveys in the future. For instance, our survey focused on only home disposal and not how patients dispose of DM-related medical waste when they are in other environments (eg, workplaces, restaurants, vacation locales, commercial airliners, and airports). Additionally, we did not explore how patients dispose of full sharps containers. The current choices for disposal of full containers include special municipal pickup services for medical waste, specially designated drop-off centers, and mail-back or exchange programs. Devices are also available for home destruction of needles, thereby rendering them inert and safe for disposal in household trash.[6,7] Information on different options is available through state-specific and municipality-specific sites. However, our data indicated that respondents did not visit these sites, which is another area of focus for patient education initiatives.

Another limitation is that we did not explore why a substantial number of respondents reused lancets and needles or why lancets were reused more often than insulin needles. We also did not evaluate how respondents sanitized these sharps between uses or the infection risk posed to the patient by multiple uses of the same lancet or needle.

Solving the problem of medical sharps disposal may require a multipronged approach. One possible solution is for manufacturers to provide information on local disposal methods in the package inserts for needles, insulin pump infusion sets, or CGMs. The Product Stewardship Institute[29] has advocated for sharps manufacturers, pharmaceutical manufacturers, or both to pay for and manage sharps take-back programs. Diabetes educators could be provided more in-depth training about regionally specific guidelines on medical waste disposal. However, point-of-care education, although important, may not fulfill the need for greater awareness of this topic, and a larger public health campaign may be required.

Despite these limitations, the study identified several areas that require further investigation. Although most respondents were properly disposing of DM-associated medical sharps, approximately one-third used unsafe disposal practices. Extrapolated over the millions of people with DM in the United States, unsafe disposal could result in millions of sharps in the MSW stream, thereby posing a substantial public health hazard. Because of the increasing prevalence of DM, expanded studies with larger numbers of patients are needed to determine their sharps-disposal practices. Improved education about how to safely dispose of sharps is needed for patients and their at-home caregivers. A broader discussion of the environmental effects of DM management is warranted.

Authors' Note

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Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

References

1. Centers for Disease Control and Prevention. *National Diabetes Statistics Report 2017*. Available at: https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf. Accessed July 3, 2019.
2. Selvin E, Parrinello CM, Daya N, Bergenstal RM. Trends in insulin use and diabetes control in the U.S.: 1988-1994 and 1999-2012. *Diabetes Care*. 2016;39:e33-e35.
3. Environmental Research & Education Foundation. *Household needles in municipal solid waste (MSW): policy, controls, and material recovery facility (MRF) safety*; 2018. Available at: https://erefdn.org/product/household-needles-in-municipal-solid-waste-msw-report-pdf/. Accessed July 3, 2019.
4. US Food & Drug Administration. DOs and DON'Ts of Proper Sharps Disposal [Internet]; 2018. Available at: https://www.fda.gov/medical-devices/safely-using-sharps-needles-and-syringes-home-work-and-travel/dos-and-donts-proper-sharps-disposal. Accessed July 3, 2019.
5. Arakawa M, Ebato C. Risk of needlestick injury in the use of plastic bottles as containers for needle disposal. *J Diabetes Sci Technol*. 2014;8:1247-1248.
6. Environmental Protection Agency. *Protect yourself, protect others: safe options for home needle disposal*; 2006. Available at: https://www.epa.gov/sites/production/files/2016-02/documents/med-home_0.pdf. Accessed July 3, 2019.
7. US Food & Drug Administration. *Be smart with sharps* [Internet]. Available at: https://www.fda.gov/media/87634/download. Accessed July 3, 2019.
8. SafeNeedleDisposal.org: Safety is the point [Internet]; 2019. Available at: https://safeneedledisposal.org/. Accessed July 3, 2019.
9. Arizona Department of Environmental Quality. Medical sharps disposal [Internet]; 2019. Available at: https://azdeq.gov/Sharps. Accessed July 3, 2019.
10. Huang L, Katsnelson S, Yang J, Argyrou C, Charitou MM. Factors contributing to appropriate sharps disposal in the community among patients with diabetes. *Diabetes Spectr*. 2018;31:155-158.

11. Costello J, Parikh A. The sticking point: diabetic sharps disposal practices in the community. *J Gen Intern Med*. 2013;28:868-869.
12. Govender D, Ross A. Sharps disposal practices among diabetic patients using insulin. *S Afr Med J*. 2012;102:163-164.
13. Olowokure B, Duggal H, Armitage L. The disposal of used sharps by diabetic patients living at home. *Int J Environ Health Res*. 2003;13:117-123.
14. Basazn Mekuria A, Melaku Gebresillassie B, Asfaw Erku D, Taye Haile K, Melese Birru E. Knowledge and self-reported practice of insulin injection device disposal among diabetes patients in Gondar town, Ethiopia: a cross-sectional study. *J Diabetes Res*. 2016;2016:1897517.
15. Majumdar A, Sahoo J, Roy G, Kamalanathan S. Improper sharp disposal practices among diabetes patients in home care settings: need for concern? *Indian J Endocrinol Metab*. 2015;19:420-425.
16. Ishtiaq O, Qadri AM, Mehar S, et al. Disposal of syringes, needles, and lancets used by diabetic patients in Pakistan. *J Infect Public Health*. 2012;5:182-188.
17. McConville DE, Hamilton EM. Syringe disposal practices and gender differences. *Diabetes Educ*. 2002;28:91-98.
18. Guardian Connect: system user guide [Internet]. Medtronic MiniMed, Inc; 2018. Available at: https://www.accessdata.fda.gov/cdrh_docs/pdf16/P160007c.pdf. Accessed July 3, 2019.
19. Dexcom G6 Continuous Glucose Monitoring System: User Guide [Internet]. Dexcom, Inc; 2019. Available at: https://s3-us-west–2.amazonaws.com/dexcompdf/G6-CGM-Users-Guide.pdf. Accessed July 3, 2019.
20. t:slim insulin pump: user guide [Internet]. Tandem Diabetes Care, Inc; 2017. Available at: https://www.tandemdiabetes.com/docs/default-source/product-documents/tslim-insulin-pump/updated-t-slim-user-guide.pdf. Accessed July 3, 2019.
21. MiniMed 670G System: Changing the quick-set infusion set quick reference guide [Internet]. Medtronic MiniMed, Inc; 2017. Available at: https://www.medtronicdiabetes.com/sites/default/files/library/download-library/workbooks/MiniMed%20670G%20with%20MiniMed%20Quick-set%20QRG.pdf. Accessed July 3, 2019.
22. Omnipod insulin management system: user guide [Internet]. Insulet Corporation; 2017. Available at: https://www.myomnipod.com/sites/default/files/inline-files/17845-5A%20Guide%2C%20Eros%20US%20User%20Guide%20Rev%20B.pdf. Accessed July 3, 2019.
23. Velagaleti R, Burns PK, Gill M, Prothro J. Impact of current good manufacturing practices and emission regulations and guidances on the discharge of pharmaceutical chemicals into the environment from manufacturing, use, and disposal. *Environ Health Perspect*. 2002;110:213-220.
24. Daughton CG. Cradle-to-cradle stewardship of drugs for minimizing their environmental disposition while promoting human health. I. Rationale for and avenues toward a green pharmacy. *Environ Health Perspect*. 2003;111(5):757-774.
25. Daughton CG. Cradle-to-cradle stewardship of drugs for minimizing their environmental disposition while promoting human health. II. Drug disposal, waste reduction, and future directions. *Environ Health Perspect*. 2003;111(5):775-785.
26. Management of used and unused insulin. Aberdeen Proving Ground, MD: US Army Public Health Command; 2019. Available at: https://phc.amedd.army.mil/PHC%20Resource%20Library/Management_of_Used_and_Expired_Insulin_FS_37-060-0913.pdf. Accessed September 5, 2019.
27. Cook CB, Wellik KE, Fowke M. Geoenvironmental diabetology. *J Diabetes Sci Technol*. 2011;5:834-842.
28. Pfutzner A, Musholt PB, Malmgren-Hansen B, Nilsson NH, Forst T. Analysis of the environmental impact of insulin infusion sets based on loss of resources with waste. *J Diabetes Sci Technol*. 2011;5:843-847.
29. Product Stewardship Institute. Medical sharps. 2019. Available at: https://www.productstewardship.us/page/Medical-Sharps. Accessed September 5, 2019.