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Effect of the Automatic Needle Destroyer on Healthcare Providers' Work in an Emergency Department: A Mixed-Methods Study

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Objectives: This study introduced a novel Automatic Needle Destroyer (AND) to an emergency department (ED) and assessed its effect on healthcare providers' work. **Methods:** Between August and September 2019, in the ED of a tertiary hospital in Seoul, we conducted a mixed-methods study to evaluate the efficiency, safety, and usability of the AND using video analysis, surveys, and in-depth interviews, wherein participants described the advantages and disadvantages of the AND. **Results:** Compared to the existing method, introducing the AND significantly reduced the operating time from 2.32 ± 1.14 seconds to 1.77 ± 3.71 seconds ($p < 0.001$). The normal operation rate was 90.6%. The rate of needle-stick injuries (NSIs) and the mean system usability scale (SUS) showed no significant differences. The in-depth interviews indicated that the disadvantages of the AND were mostly operational. The advantages were related to profit, reduced direct contact with hazardous waste, and behavioral changes, such as not having to recap syringes. **Conclusions:** We introduced the AND to an ED environment, where NSIs occur frequently and many syringes are used, to evaluate its effect on providers' work. The AND reduced the time for needle disposal, but the normal operation rate was low. No significant differences were found in the SUS score or the rate of NSIs. Although there are some restrictions on introducing the AND immediately, this study's results showed its potential usefulness. Efforts to improve the operation of the device and a longer study period are needed to fully achieve safety and efficiency.

Keywords: Emergency Service, Hospital, Occupational Health, Needlestick Injuries, Protective Devices, Feasibility Studies

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I. Introduction

Needle-stick injuries (NSIs) are the most frequent occupational injuries experienced by healthcare providers (HCPs) around the world [1,2]. NSIs are dangerous because bloodborne pathogens in patients can infect HCPs [1,3]. In addition to affecting the health of HCPs, NSIs impose costs on HCPs and society because they necessitate examinations, treatment, and the loss of human resources [2,4,5].

Therefore, many efforts have been made to analyze the causes of NSIs and ways to reduce them. The main causes of NSIs can be classified as engineering-related factors (e.g., the

form of sharp devices and barrier devices), organizational factors (e.g., the methods and policies for reporting), and behavioral factors (e.g., recapping and disposal) [2,6,7]. Safety devices have been used to prevent NSIs. Many interventional studies used safety syringes to reduce NSIs, and several types of needle destroyers have been designed to dispose of syringes [8,9]. However, only a few interventional studies using these devices have been conducted in a medical environment [10].

In this study, the researchers introduced a new needle-destroying device, called the Automatic Needle Destroyer (AND), which separates the needle from the syringe for disposal. We hypothesized that the AND would be beneficial in an emergency department (ED), where many syringes are used. Therefore, we evaluated the efficiency, safety, and usability of the AND in a real medical environment.

II. Methods

1. Overall Study Design

This was a mixed-methods interventional study using the AND invented by the MUNE Corporation (Seoul, Korea). This study was supported by a Bio/Healthcare Commercialization Support Program grant through the Incheon Center for Creative Economy and Innovation. The researchers conducted this study and had no conflicts of interest. The study protocol was approved by the Institutional Review Board of Samsung Medical Center (No. 2019-05-112-001). This study was registered at clinicaltrials.gov (Identifier: NCT04039906).

1) Setting

The study was conducted in an ED of a 1,989-bed tertiary academic hospital in Seoul. This department treats more than 70,000 patients annually and is evaluated as providing high-quality emergency care according to the national emergency patient care information network. Syringes and needles are disposed of according to the hospital's standard procedure for dealing with biohazardous materials. The waste disposal process did not change when the AND was used.

2) Design

We designed this study to derive valid results from comprehensive and corroborative data obtained through quantitative and qualitative means.

This study was conducted over 3 weeks, including a pre-intervention week (the first week), a preparation week (the second week), and an intervention week (the third week) (Figure 1). We set each period to last for a week as it was difficult to apply the new system for a longer period in the complex ED environment. Furthermore, nurses' duties changed weekly.

We designated 10 of the 15 candidate sites in the ED for testing. In the pre-intervention week, syringes were manually removed by the existing method without the AND. In the preparation week, AND systems were installed and instructions (in the form of a video description of the product during shifts) were provided explaining how to use the AND. In the intervention week, study participants removed syringes manually or automatically with the AND at their convenience. During the first week and third week, outcomes were derived through video footage of syringe processing. Surveys

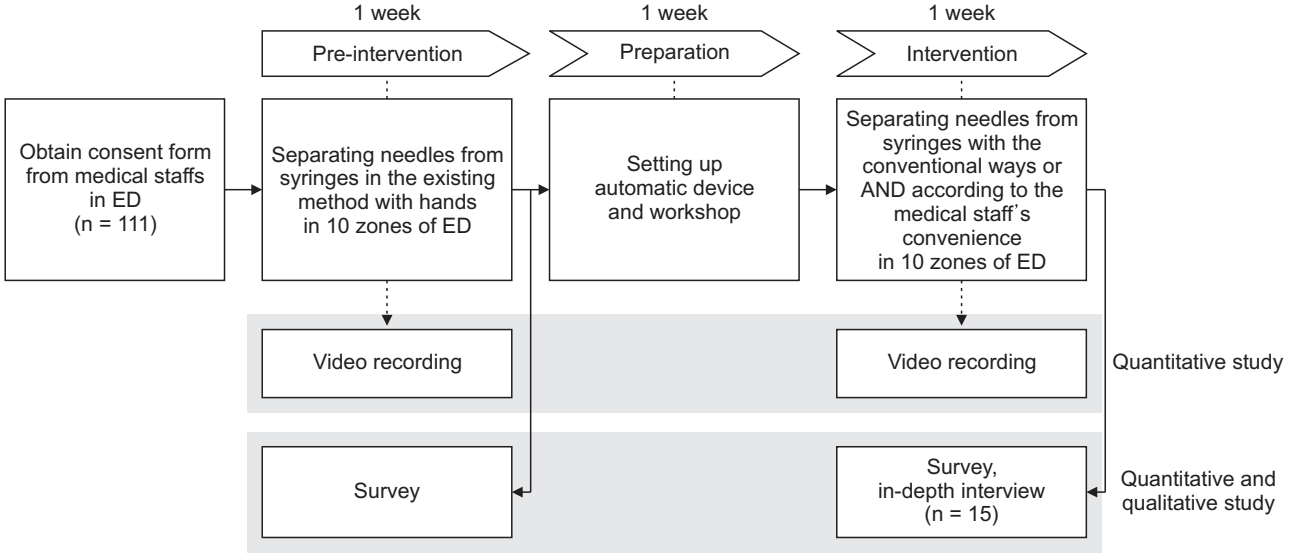

Figure 1. Study design and population. ED: emergency department, AND: Automatic Needle Destroyer.

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were conducted after the first and third weeks, and 15 participants were interviewed after the third week.

3) Overview of the AND

The AND attaches to an existing sharps container cart or a fixed container. When a syringe is inserted into the AND, it cuts the needle and disposes of it at once (Figure 2). In its original configuration, the AND used infrared light to recognize the syringe, but a button was used in the present study to operate it manually to ensure accuracy. The AND can handle both capped and uncapped syringes.

There are some potential dangers when using the AND. For instance, it can malfunction when misused or if the blade is blunt. The AND can also handle only certain types of syringes. Occasionally, the AND operates without an inserted syringe because of its sensitive sensor. We informed HCPs of these issues to protect them from harming either themselves or patients.

2. Video Analysis

1) Participants and sample size

This study compared outcomes before and after the device was used by the same people in the same setting. From August to September 2019, 111 HCPs in the ED were recruited for this study. HCPs were excluded if they were younger than 19 years or declined to participate. Informed consent was obtained from all participants.

We calculated the sample size based on syringe usage over an intervention period of 1 week, not the number of HCP participants. We assumed that about 6,500 syringes would be used in each the pre-intervention week and the intervention week based on experience by ED nurses. According to the central limit theorem, about 6,500 cases were deemed to be sufficient to compare the average time for needle disposal.

2) Study variables

Efficiency was evaluated by monitoring the daily use of the AND. We monitored how many syringes were disposed of in the AND, the normal operation rate of the AND, and the average syringe processing time using existing methods or the AND. Outcomes were derived through video footage of syringe processing that was obtained by installing a camera in the ED. The participants' faces did not appear in the videos. The data recorded were instances of the device's use.

3) Data analysis

Two people viewed each video. They were required to reach a consensus about the start and endpoint of the needle's disposal to within a millisecond. The start point was the moment the needle was laid on the sharps container or in the AND. The endpoint was the moment the needle landed on the sharps container. We calculated efficiency using descriptive analyses, such as mean ± standard deviation (SD), the Wilcoxon rank-sum test, and counting. Data analyses were conducted using R software, version 3.3.1 (R Foundation, Vienna, Austria).

3. Survey

1) Participants and sample size

In total, 111 participants were surveyed.

2) Study variables

(1) Demographics: Variables such as sex, age, occupational group, and work history were investigated.

(2) Safety: We performed a survey to determine the current status of NSIs. The questions covered the number of NSIs,

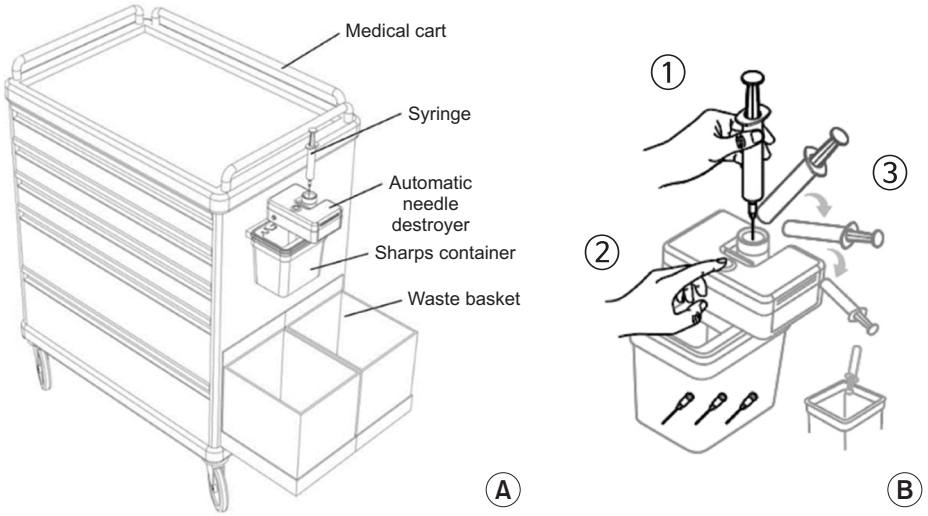

Figure 2. Installation and directions for the Automatic Needle Destroyer (AND). (A) Installation of the AND: the AND is installed on top of the sharps container in the medical cart. (B) Directions for the AND: ① a user places the syringe at the syringe inlet, ② the user presses the button, ③ the needle and needle connections are cut by a blade. The needle is separated into a sharps container and the body is separated into a wastebasket.

the devices that caused NSIs, and the exact nature of NSIs. We evaluated the incidence of NSIs in the pre-intervention week and the intervention week.

(3) Usability: The System Usability Scale (SUS) was applied to assess the usability of existing methods and the AND for removing needles. The SUS scale was employed in its most widely used format, without modifications (Appendix 1).

3) Data analysis

We obtained data on participants' demographic characteristics. For questions about NSIs, we analyzed the frequency, tendencies, and keywords of the answers to each question to determine the causes of NSIs and participants' thoughts on them. We calculated the NSI rate using the number of syringes recorded by video and the number of NSI occurrences described in the surveys. We compared the NSI rates in the pre-intervention and intervention weeks by two independent-population proportions tests. We also compared the mean SUS scores ± SD between existing methods and the AND using the paired *t*-test.

4. In-Depth Interview

1) Participants and sample size

We interviewed 15 people via convenience sampling. We interviewed more nurses than doctors because nurses are the primary users of syringes.

2) Study variables and data analysis

We asked thematically relevant questions, with a particular focus on the AND. We recorded all interviews with permission and transcribed them for analysis. Next, we analyzed the frequency, tendency, and keywords of the answers to each question and categorized them as related to the efficiency, safety, and usability of the AND.

III. Results

1. Demographics

A total of 111 HCPs at risk for NSIs participated in this study. There were more women than men. Most were in their 20s to 30s (96.4%). Over half of the HCPs (50.5%) had been working for under 3 years. Their characteristics are presented in Table 1.

Table 1. Demographic characteristics of the study participants

Characteristic	n (%)
Sex	
Male	25 (22.5)
Female	86 (77.5)
Age (yr)	
20–29	73 (65.8)
30–39	34 (30.6)
40–49	3 (2.7)
≥50	1 (0.9)
Profession	
Nurse	88 (79.3)
Doctor	23 (20.7)
Work history (yr)	
<3	56 (50.5)
3–5	22 (19.8)
5–10	22 (19.8)
>10	11 (9.9)

2. Video Analysis: Efficiency

1) Utilization rate

The AND usage for each day of the intervention week was consistent. Two types of needles can be processed by the AND: general syringes and Luer-Locks (Merck, Burlington, MA, USA). In the intervention week, a total of 3,720 general syringes and Luer-Locks were used, of which 2,114 (56.8%) were processed with the AND.

2) Processing time and normal operating rate

The average times for syringe disposal were compared, assuming a normal disposal time of <10 seconds. The average processing time using the existing manual method was 2.32 ± 1.14 seconds and 1.77 ± 3.71 seconds for the AND. The median processing time using the existing manual method (2 seconds; interquartile range [IQR], 1) and the median processing time using the AND (1 second; IQR, 0) were significantly different ($p < 0.001$). To calculate the normal operation rate of the AND, device malfunction was defined as an operation time greater than 2 seconds, based on the existing method's average time of 2.32 seconds. The number of syringes processed manually was 3,958, of which 111 were discarded without removing the needles. Most syringes and needles (97.20%) were separated and discarded as recommended. There were 2,114 syringes processed by the AND, of which 1,916 (90.6%) were normally processed and 198 were not processed due to a malfunction (9.4%). Thus, the normal operation rate of the AND was 90.6%.

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3. Survey

1) Safety of existing methods

Eighty-eight nurses and 23 doctors were surveyed to assess instances of NSIs, including the needles that caused NSIs, when NSIs occurred, and HCPs' work experience at the time of NSIs. These questions dealt with all participants' work experience with no time limit.

Two hundred and fifty-seven NSIs occurred, most commonly with general syringes (47.5%), butterfly needles (20.6%), and intravenous catheters (20.2%). The needles causing NSIs varied according to the cause of the NSI. NSIs occurred more frequently during disposal than in preparation for treatment or at a patient's bedside (Figure 3).

2) Safety: NSI occurrence during the study period

During the pre-intervention week, there were seven NSIs, of which two were with general syringes in the disposal process. During the intervention week, three NSIs occurred, one of which was with a general syringe in the disposal process. The NSI rate for using a general syringe that the AND could dispose of was 0.03% in both weeks, which was not significantly different (p = 1.00) (Table 2).

3) Usability (SUS)

The mean SUS score was 65.7 ± 13.1 for the existing disposal method and 62.6 ± 15.8 for the AND. This difference was not statistically significant (p = 0.14) (Table 3).

4. In-Depth Interviews

The interviews focused on the advantages and disadvantages of the AND in terms of efficiency, safety, and usability. The participants' answers are shown in Table 4.

IV. Discussion

1. Rationale for a Mixed-Methods Study

We designed this study with a convergent mixed-methods model to obtain valid results based on comprehensive and corroborative data. The quantitative study for the AND was intended to elicit a diverse range of maximally objective outcomes through video recordings made at real clinical sites and the use of the SUS, an objective usability scale. A qualitative study was also conducted to evaluate usability and experiences through participants' opinions. The AND reduced the syringe disposal time compared to the existing method,

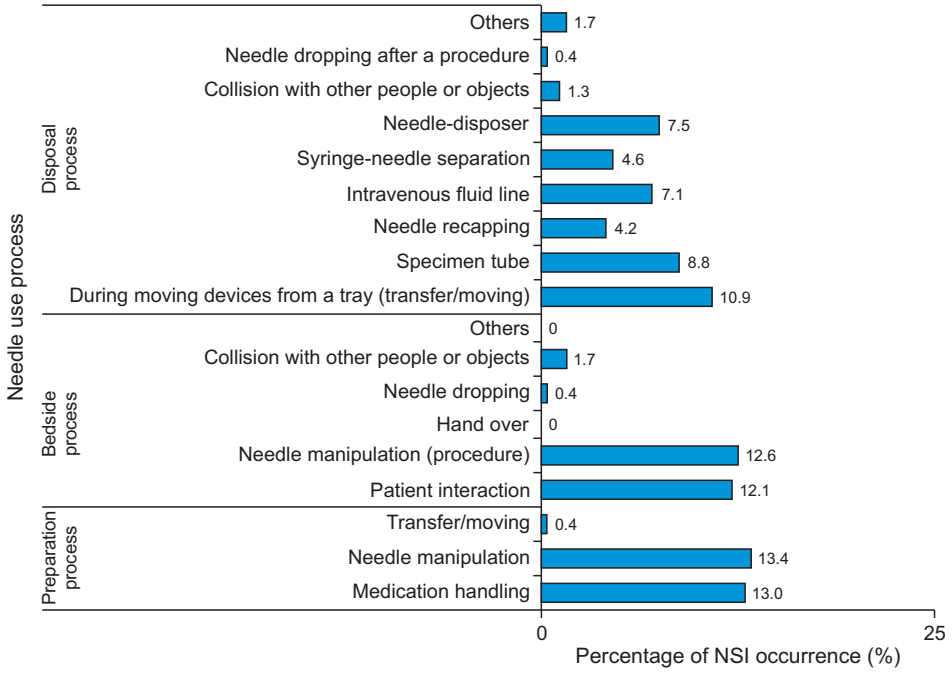

Figure 3. Percentage of needle-stick injury (NSI) occurrence by needle use stage.

Table 2. Comparison of the NSI rate in the needle disposal stage between the pre-intervention week and the intervention week

	Pre-intervention week	Intervention week	p-value
Total number of needles disposed	3,958	3,720	
Total number of NSI	2	1	
NSI rate (%)	0.05	0.03	1.00

NSI: needle-stick injury.

Table 3. Mean SUS scores for existing methods and the Automatic Needle Destroyer

Profession	Work history (yr)	n	Pre-intervention week	Intervention week	*p*-value
Total		111	65.7 ± 13.1	62.6 ± 15.8	0.14
Nurse		88	66.1 ± 12.7	62.8 ± 16.2	0.16
	<3	43	66.7 ± 11.0	62.5 ± 17.0	
	3–5	16	67.67 ± 16.4	62.2 ± 15.7	
	5–10	19	68.2 ± 13.0	62.2 ± 16.0	
	>10	10	57.5 ± 10.6	66.0 ± 16.6	
Doctor		23	63.8 ± 14.5	61.8 ± 14.0	0.64
	<3	13	61.2 ± 16.0	56.7 ± 11.4	
	3–5	6	59.6 ± 7.81	66.9 ± 13.3	
	5–10	3	80.8 ± 7.22	75.8 ± 17.0	
	>10	1	72.5	-	

Values are presented as mean SUS score ± standard deviation.
SUS: system usability score.

Table 4. Advantages and disadvantages of the Automatic Needle Destroyer (AND) derived from interviews

		Comment
Safety	Advantage	Reduced risk of needle-stick injury by decreasing direct contact with hazardous waste.
		Behavioral changes occurred – not having to recap syringes.
	Disadvantage	Needle entrapment, bouncing, and incomplete removal due to blunt blade, etc.
Efficiency	Advantage	Free-field syringe removal reduced working hours.
		Sharps container was filled slower than before.
	Disadvantage	Did not deal with all syringes.
		Required extra instrument maintenance personnel.
		Low accessibility using the machine. It could be used only if it was installed.
		More expensive due to machine purchase and other consumables.
		Difficult to use in complex places.
Usability	Advantage	Required less wrist strength to remove a syringe.
		Convenient and easy to use.
	Disadvantage	Sometimes malfunctioned because of a sensitive sensor.
		Incomplete adjustment of mechanical force prevented needles from entering the wastebasket.
		The weak connection between the AND and the sharps container.

but failed to replace the existing method completely, and the SUS score for the AND did not differ significantly from the current process, indicating that the AND seemed to be less effective. However, the qualitative results showed positive reviews of the device, which would not have been clear based on the quantitative results alone.

2. Rationale for the ED as Locale

EDs operate 24 hours per day. HCPs in EDs have a greater risk of sharps injuries than other departments and NSIs are more frequent [3,11]. A previous study found that a significant portion of NSIs and sharps injuries (52.0%) occurred with ordinary syringes and during recapping [12-14], and removing a needle from a syringe or placing a needle in a full medical waste container was identified as the most common cause of NSIs [12,15]. Thus, it was meaningful to evaluate the effectiveness of the AND in an actual ED environment.

3. Strengths of Our Study Compared to Previous Studies

When introducing an engineered safety device, it is important to consider the device's performance, safety, and user satisfaction [16]. Moreover, because of the tradeoff between effectiveness and safety, a comprehensive range of aspects should be analyzed [17]. Previous studies often only investi-

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gated NSI reduction as an indicator of safety. However, this study is meaningful in that it analyzed the device's introduction through a multifaceted approach examining efficiency, safety, and availability, rather than a single outcome.

Healthcare safety issues result from complex interactions between providers, patients, and medical devices. NSIs do not occur only at a particular place or moment. Therefore, NSIs should be considered in the overall process of handling needles. For example, improvements in the disposal process may affect needle use more generally, such as reducing needle recapping, which is not a direct disposal method and is closely related to NSIs. It is difficult to change the existing system using only one simple device. However, we sought to understand NSIs as an overall phenomenon involving how needles are handled within the ED, as well as container-related NSIs at the disposal stage. This study can be used as a basis for further research.

4. Interpretation of the Negative Quantitative Results

1) Lack of significance for the NSI rate: the ED environment

The reason for the lack of a significant improvement in the NSI rate may relate to the nature of an ED. Because an ED is a more complex environment than other hospital environments and is a setting where NSIs frequently occur, the short period of the study and the fact that the AND could only lead to improvements in the disposal phase might explain the lack of a significant impact on the incidence of NSIs in the ED, where many factors are present. In addition, previous studies rarely showed a significant reduction in NSIs before and after introducing safety containers [10,18,19].

2) Lack of significance for the NSI rate and SUS score: limitations of disposed syringe types and the short study period

If the AND had handled a broader range of syringe types and been placed in more locations in the ED, better results may have been found in terms of NSI reduction and the SUS score. Furthermore, we might not have had sufficient time to compare usability and NSI reduction. A longer study may be necessary in light of the time needed for new behavioral changes to be established after the introduction of new devices.

3) Operating time reduction and the normal operating rate

The average time for needle disposal decreased from 2.32 to 1.77 seconds using the AND, with a malfunction rate of 9.4%. This time difference is insufficient and unacceptable. However, this finding demonstrates that efforts would be needed to increase the normal operation rate of the device in the clinical environment, not just in the experimental setting, because several factors related to the device's operation play a role in the clinical field. When the AND is introduced to actual clinical practice accompanied by efforts to improve the normal operation rate of the device, the workflow might not be disrupted because there is not a substantial time difference from the existing needle removal method.

5. Limitations

First, this study was conducted in only one department at a single hospital. Therefore, it is difficult to generalize the effectiveness of the introduction of this device. We need to expand the study to more hospitals. Second, the skills and familiarity of HCPs with the AND were not evaluated. Previous research on the application of new devices was generally conducted over more than 1 year. Although the AND is considered simple to use, it may not be sufficient to compare only 1 week of use with the much longer periods analyzed in previous research. Third, the study period was insufficient to examine the NSI rate because NSIs are rare. We designed this study to compare outcomes before and after the introduction of the device, considering the number of syringes used. Therefore, we believe that a more extended period of testing will be required to examine the decrease in NSIs. Fourth, we investigated NSIs only using the participants' recall. Therefore, more accurate methods are necessary to obtain information on the actual occurrence of NSIs.

6. Conclusion

The AND reduced the time for needle disposal, but the normal operation rate was not adequate. The SUS score for the AND was not significantly different from that of the existing method, and introducing the AND did not reduce the NSI rate. In the in-depth interviews, HCPs said the main disadvantages were related to the operational aspects of the device. The advantages were related to benefits when using the AND, such as decreasing direct contact with hazardous waste, not having to recap syringes, and needing less wrist strength. Although there are some restrictions on introducing the AND right away, this study showed its potential usefulness, which could be enhanced by efforts to improve the device's operability. A longer study period is needed to fully achieve safety, efficiency, and safety.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Appendix 1. System Usability Scale (SUS) questionnaire

		Strongly disagree				Strongly agree
Q1	I think that I would like to use this system.	1	2	3	4	5
Q2	I found this system unnecessarily complex.	1	2	3	4	5
Q3	I found this system was easy to use.	1	2	3	4	5
Q4	I think that I would need the support of a technical person to be able to use this system.	1	2	3	4	5
Q5	I think the various functions in this system were well integrated.	1	2	3	4	5
Q6	I thought there was too much inconsistency in this system.	1	2	3	4	5
Q7	I would imagine that most people would learn to use this system very quickly.	1	2	3	4	5
Q8	I found the system very cumbersome to use.	1	2	3	4	5
Q9	I felt very confident using this system.	1	2	3	4	5
Q10	I needed to learn a lot of things before I could get going with this system.	1	2	3	4	5