Automatic MDCT Injectors: Hygiene and Efficiency of Disposable, Prefilled, and Multidosing Roller Pump Systems in Clinical Routine

OBJECTIVE. This study evaluated three different injection systems with regard to microbiological contamination, time efficiency, and user handling during a clinical routine.

SUBJECTS AND METHODS. A total of 825 patients were included. A double-syringe contrast injector with disposable syringes (system A; $n = 150$) and one that used prefilled syringes (system B; $n = 150$) were microbiologically analyzed during single use of the syringes in one patient. Moreover, the contamination of a roller pump injector capable of multidosing several patients from a contrast agent container, without the need for prior filling, was determined after being used for an entire day (system C; $n = 35$ injections/day for 15 days). The hygienic background was guaranteed by taking imprints of the surfaces of devices and the palms of the hands of members of CT staff before the clinical investigation. The time required for assembly of the injection systems and for filling or refilling of each injector system was measured. The handling of the three systems also was subjectively ranked by the technicians.

RESULTS. Injection systems A, B, and C remained microbiologically sterile and free of contamination throughout their use in clinical routine. The mean ($\pm$ SD) time for injection system assembly and installation of syringes and filling did not differ significantly between injection systems A and B (system A, $2.5 \pm 1.1$ minutes; system B, $1.9 \pm 1.3$ minutes; $p = 0.12$), whereas the time for assembly of system C was significantly shorter ($0.9 \pm 0.6$ minutes; $p < 0.05$ vs system A; $p < 0.05$ vs system B). In the subjective ranking of injector handling, systems B and C were preferred.

CONCLUSION. Double-syringe injectors used with disposable or prefilled contrast agent syringes, as well as roller pump injectors, ensure hygienic conditions in clinical routine. However, time efficiency and handling are aspects that favor prefilled and roller pump systems.

Automatic injectors for IV application of contrast agent and saline allow an efficient and optimized workflow and have become a standard in MDCT over the last decade [1–6]. According to national restrictions by regulatory authorities, such as the US Food and Drug Administration, the syringes, disposable tubes, and connectors used with automatic injectors are approved for single use only. In fact, the frequent handling of syringes during injector assembly and filling or refilling of syringes during multiple uses has been considered as the basic cause of microbiological contamination [7–9]. Recent clinical studies documented microbiological contamination of syringes for contrast agent and saline in the case of multiple use in more than one patient or application procedure [10]. Only the single use of conventional injection syringes in one patient ensures hygienic conditions and sterility of the CT injection system but might hamper the time-efficient use of automatic injectors in daily routine.

As a result of such developments, certain companies have recently offered prefilled disposable contrast agent syringes. These systems can also be used in double-syringe CT injectors and are suggested to combine proper microbiological conditions with more time-efficient handling of injectors as the result of reduced manipulation by the technical staff during injector assembly because there is no need for syringe filling [11]. The roller pump injectors now on offer deliver the injection directly from a contrast agent and saline container through a special injection tube. Hence, syringe replacement or filling is not necessary before each application procedure. Injector certifications ap-
Hygiene and Efficiency of Three Different Automatic MDCT Injector Systems

**Subjects and Methods**

**Patients**

A total of 825 patients (one application per patient for 825 application procedures; 489 male subjects and 336 female subjects; mean age, 51 years; range, 14–87 years) with a clinical indication for contrast agent bolus injection. The injection tube is adapted to the tube system. By compression of the pump tube, contrast agent and saline are pumped forward. The injection tube is adapted to the patient tube containing two one-way valves to avoid retrograde flow. The patient tube is changed for each new patient, whereas the injection tube is certified for use up to 24 hours (Fig. 3).

**Injection Systems and Syringes**

The MDCT (Somatom Definition, Siemens Healthcare) examination protocols used in this study consisted of one or more contrast agent bolus injections for single or multiple contrast phases (up to 140 mL of contrast agent adapted to common clinical CT examination protocol), followed in each case by a saline chaser (80 mL of 0.9% sodium chloride).

**Double-Syringe CT Injector**

The double-syringe CT injector (Stellant CT Injection System, Medrad) comprises two injection syringes, one for contrast agent and another for saline, which are connected by a T-shaped connector. A one-way valve is placed in the contrast agent crural of the injection tube to avoid infiltration of saline into the contrast agent syringes; bacterial filters are not integrated into the lines. A T-shaped connector placed in the saline crural allows filling of the contrast agent and saline from saline supply.

**System A**—With system A, disposable syringes (volume, 150 mL; Stellant Syringe Kit, Medrad) that have to be filled manually from a contrast agent and saline supply were used for contrast agent (Ultravist-370, Bayer Schering Pharma) and saline bolus application (Fig. 1).

**System B**—With system B, prefilled disposable syringes containing iodinated contrast agent (150-mL prefilled syringe; Ultravist-370, Bayer Schering Pharma) were used for contrast-enhanced CT examinations. Conventional disposable syringes (volume, 150 mL), which have to be filled from a saline supply before injection, were used for saline injection (Stellant Syringe Kit, Medrad) (Fig. 2).

**Roller Pump Injector: System C**

The roller pump injector (Mississippi, Ullrich Medical) delivers the injection directly from the contrast agent and saline supplies. Contrast agent and saline supply are connected by a special trident-shaped pump tube accessing one saline and two contrast agent supply reservoirs (two-part hose system, Ullrich Medical). A particle filter prevents infiltration of microparticles into the tube system. By compression of the pump tube, contrast agent and saline are pumped forward. The injection tube is adapted to the patient tube containing two one-way valves to avoid retrograde flow. The patient tube is changed for each new patient, whereas the injection tube is certified for use up to 24 hours (Fig. 3).

**Hygienic Background: Bacterial Contamination of Palms and Surfaces**

Adequate hygienic conditions in terms of the palms of the hands and work surfaces (i.e., hygienic background) are essential when operating automatic injectors. An inadequate hygienic background may contribute to the contamination of injection systems. Therefore, bacterial contamination of palms and surfaces in the CT unit was evaluated before clinical investigation to ensure an adequate hygienic background.

To achieve this aim, staff and technical equipment (including surfaces and so forth) of the CT department underwent intensive and continuous hygienic surveillance by the infection control personnel of the Institute of Microbiology and Hygiene at our institution. On the basis of the recommendations made in previous studies, the technical and medical staff received regular hygiene instruction every 6 months to promote appropriate hygiene practices. The medical and technical staff were urged to perform sufficient hand disinfection before and after each contact with a patient (e.g., patient reception and positioning), as recommended by the national guidelines issued by the federal institute responsible for disease control and prevention (Robert Koch Institute, Berlin, Germany). As part of standardized
Buerke et al.

The imprints of the palms and surfaces were taken directly after disinfection; otherwise, 10 mL of tryptic soy broth that was subsequently also injected into 100-mL tryptic soy broth bottles. Air filters were connected to all bottles before incubation to allow aerobic bacterial growth. After 7 days of incubation, the bottles were visually inspected and, in the event of any suspected turbidity indicative of growth of microorganisms, 100 µL of the broth was streaked onto Columbia blood agar plates (Model 109e, Heipha Dr. Müller GmbH). After 48 hours of incubation, the plates were visually inspected and, if bacterial growth was detected, the colonies were differentiated using standard microbiological techniques. All incubation steps were performed at 37°C under aerobic conditions.

Data interpretation and statistics—The results of microbiological analysis were evaluated in thresholds and interpreted as “clinical observations.” The bacterial contamination of surfaces and palms was counted in CFU. Each surface and palm was considered separately. Statistical analysis using averages of different surfaces and palms therefore was not applicable. In summary, the contamination of surfaces and palms gave an overview of the hygienic conditions (i.e., hygienic background) in which this clinical study was performed. In particular, contamination with nosocomial pathogens (e.g., Staphylococcus aureus, Pseudomonas aeruginosa, and Candida species) or with microorganisms indicating fecal contamination (e.g., Enterococcus species or Enterobacteriaceae) was rated as “unacceptable” irrespective of the CFU. Detection of normal dermal or environmental flora (e.g., coagulase-negative staphylococci and Bacillus species) was rated depending on the CFU count and the state of disinfection: the threshold for acceptance was 20 CFU only for imprints taken directly after disinfection; otherwise, higher CFU counts (≤ 40 CFU) of normal flora were rated as “acceptable.”

Contrast agent and syringes are designated for parenteral application. Every incident of microbiological contamination has to be evaluated as “contaminated.” CFU values are not applicable.

The time for injector assembly and filling or refilling of syringes for system A or B, or for the use of conventional syringes for contrast agent and saline, was statistically analyzed using the Student’s t-test (p < 0.01).

Results

Hygienic Background: Bacterial Contamination of Palms and Surfaces

Microbiological analysis of the imprints (n = 150) of the palms of the hands of medical and technical staff, as well as of the surfaces in the CT unit during clinical routine, revealed bacterial contamination with typical skin flora,
such as coagulase-negative staphylococci or *Micrococcus* species, within acceptable ranges. Neither the imprints of the surfaces nor the hands were contaminated with nosocomial pathogens or fecal flora. The imprints taken during routine working practices without prior disinfection revealed readings up to 33 CFU (surfaces) and 22 CFU (hands), respectively, indicating hygienic conditions for surfaces and palms (Table 1). There was no contamination of palms or surfaces with fecal flora, which would otherwise indicate serious noncompliance with hygienic regulations.

**Bacterial Contamination of Injection Syringes**

The syringes or injection tubes of injection systems A, B, and C were microbiologically analyzed after each injection process. Microbiological analysis revealed bacterial contamination in none of the 150 disposable syringes for contrast agent and none of the 150 syringes for saline (system A), and in none of the 150 prefilled syringes for contrast agent and none of the 150 disposable syringes for saline (system B). The injection tubes also revealed no contamination. Analysis of the roller pump system (system C) showed no contamination of tubes, contrast agent, and saline containers among the 15 probes.

**Time Efficiency of Use of Injection System A (Disposable Syringes), B (Prefilled Syringes), and C (Roller Pump)**

The mean time required to assemble the double-syringe injector, including installation and filling of disposable syringes for contrast agent and saline, was 2.5 ± 1.1 minutes with system A. The mean time required to assemble the double-syringe injector (installation of the prefilled contrast agent syringes and filling of saline syringes) in system B was shorter (2.0 ± 1.4 minutes), but the difference was not statistically significant (*p* = 0.12). The mean time for tube connection and exchange of contrast agent and saline supplies between applications was significantly shorter with system C (0.9 ± 0.6 minutes; *p* = 0.05 vs system A, and *p* = 0.05 vs system B). Initial assembly of the roller pump injector, which has to be performed once before the first application procedure, including installation of the trident injection tube, took 4.5 ± 0.9 minutes on average. As outlined in further detail in Figure 4, system C outperformed systems A and B after six examination cycles.

**Subjective Ranking of Injector Handling**

The injector systems were ranked by eight technicians. For handling of initial injector assembly before first application, system B was preferred in 88% of cases, system A was preferred in 12% of cases, and system C was preferred in 0% of cases. For exchange and filling of syringes, including patient connection to the system between each examination, system C was preferred in 100% of cases, and systems B and A were preferred in 0% of cases.

**Discussion**

Rapid advances in MDCT technology have significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and saline supplies between applications was significantly reduced the scanning time of examinations to a few seconds, whereby the automatic application of contrast agent and saline bolus is essential [12–14]. Enforced by economic conditions, the time taken to assemble the injector and fill syringes needs to be shortened to achieve an efficient workflow and enable increased patient throughput. Multiple uses of disposable syringes for more than one patient in double-syringe injectors has been considered as a means of reducing the time required for injector assembly [7]. Only the equipment coming into direct contact with the patient (i.e., tube and
Data on the bacterial and microbiological contamination of contrast agents are lacking. However, recent studies have found that the multiple use of syringes is burdened by the risk of potential infectious hazards to patients because of microbiological contamination of syringes. This microbiological contamination is caused during the handling of contrast agent and saline containers and tube connection for syringe refill by the technicians and health care personnel. Additionally, contamination from the patient's microbial flora is the second most common issue. Nonionic contrast agents are also known to be microbiologically susceptible, especially if syringes for the contrast agent and saline solution are warmed to 37°C to reduce viscosity. Bacterial contamination of vials and catheters with microorganisms from the dermal flora (e.g., coagulase-negative staphylococci) and the effects of the resulting bacteremia have been studied extensively in central venous catheters and peripheral venous lines. The clinical manifestations depend greatly on immune status and range from infusion-related phlebitis to bloodstream infections, sepsis, and sepsis-related complications. Applying such observations to the parenteral application of contrast agents and saline in CT units, hygienic precautions therefore should be as strict as possible, especially for patients receiving immune suppression therapy.

As a consequence and according to national restrictions by regulatory authorities such as the U.S. Food and Drug Administration, the syringes, disposable tubes, and connectors used with automatic injectors are approved for single use only. Instead of the single use of disposable syringes, prefilled contrast agent syringes can also be used in double-syringe CT systems. Injector certifications for roller pump injectors approve multidosing (i.e., several consecutive injections from numerous agent containers using the same tube system for longer than 1 day). Both systems claim to combine proper microbiological conditions with time-efficient handling of injectors by avoiding the filling and refilling process. Consequently, this study addressed three main factors: first, hygienic conditions in terms of microbiological contamination of disposable, prefilled, and multiple-dose roller pump systems; second, efficiency of each system considering setup and usage in clinical routine; and third, subjective ranking of the different systems by the involved technicians.

Poor hygienic conditions in terms of the work surfaces in the CT department and the palms of the hands of staff would have potentially biased the results of this study. Several studies have addressed the matter of adequate hand disinfection of staff for this purpose.[8, 25–27]. In this study, the imprints during routine working practices without direct previous disinfection indicated hygienic condition of surfaces and palms.

As revealed by the results of this study, and in concordance with previous results obtained by Buerke et al. [7, 10], the single use of disposable syringes for contrast agent and saline (system A) and the use of prefilled syringes for contrast agent in combination with disposable syringes for saline (system B) prevented microbiological contamination and ensured hygienic conditions. Also, the roller pump system (system C) ensured sterility of the injection tube, despite the fact that the identical tube was used throughout the day. Reduced personal contact with the injection syringes and tubes is probably a causal factor in the optimized hygienic conditions in systems A and B. In addition, the particle filter and one-way valves incorporated in the injection tube of the roller pump system (system C) obviated possible microbiological infiltration. In contrast, multiple-use protocols have previously shown microbiological contamination with coagulase-negative staphylococci. This observation confirms that every manipulative step (e.g., refilling and injector assembly) carries the risk of contamination. Thus, if the environment is hygienic, a reduction in refilling steps by using prefilled or multidosing systems contributes toward hygienic administration of the contrast agent solutions.

Prefilled and contrast agent container systems appear to reduce the number of syringe changes and thus are more time-efficient with higher patient throughput. Comparative data on time efficiency in the handling of disposable prefilled and contrast container systems are, to the best of our knowledge, lacking. This study revealed, in fact, that syringe exchange, filling, and connection took more time for a single syringe (system A) but less time for prefilled syringes (system B). These results indicate that the use of prefilled saline syringes rather than refilling syringes for each patient contributes to even more time-efficient contrast administration for CT. Using system C, significantly less time is needed than with systems A and B, because the injection is taken directly from the contrast agent and saline containers and there is no handling time for syringe exchange and filling of syringes. In system C, however, initial injector assembly is more time-consuming in

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>System A</th>
<th>System B</th>
<th>System C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>4</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>8</td>
<td>E</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>16</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>20</td>
<td>E</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>24</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>28</td>
<td>C</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>32</td>
<td>E</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>36</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>40</td>
<td>C</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>44</td>
<td>E</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>48</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>52</td>
<td>C</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>56</td>
<td>E</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>60</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>64</td>
<td>C</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>68</td>
<td>E</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>72</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

Fig. 4—Time expenditure. Chart shows time expenditure for CT examinations using injection systems A, B, and C. After initial injector assembly (IIA), injectors are ready for daily use. Time for IIA differs with regard to injection system. Time of IIA is longest for injection system C (~4 minutes). Time of IIA for injection systems A and B is identical with time needed for syringe exchange (E), filling of syringe (F), and connection of tubes (C) between each examination. In system B, syringes do not require filling because they are prefilled. None of these procedures are necessary when using system C. Thus, time for connection is shortest in this system (0.9 ± 0.6 minutes). As can be easily deduced from chart, system C is superior with regard to time efficiency after six procedures are necessary when using system C. Thus, time for connection is shortest in this system (0.9 ± 0.6 minutes).
comparison with the injection systems A and B. However, this disadvantage is compensated for within the next six examinations (Fig. 4). Considering the greater time efficiency of systems B and C, one can extrapolate that after a workday of 30 examinations, system B saves 18 minutes and system C saves 48 minutes, compared with system A. System C saves 30 minutes in comparison with system B. Projected to 200 workdays per year, system B saves 3600 minutes, equivalent to 8 workdays, and system C saves up to 9600 minutes, equivalent to 20 workdays per year, compared with the single use of syringes. System C saves 6000 minutes, equivalent to 12 workdays, compared with a prefilled syringe. The time saving especially with system C (6–10%), therefore, may be the basis for higher patient throughput. The multiple use of contrast and saline syringes is widely believed to be more time-efficient with higher patient throughput. Previous work has indicated, however, that the benefit is outweighed by the time lost with filling and refilling the syringes [11]. Indeed, when compared with published data [11], multiple use of syringes takes longer (3.1 ± 1.3 minutes) than our protocols with prefilled and multi-dosing systems. In view of the more time-efficient handling of prefilled and roller pump systems, multiple use of syringes, which poses a potential infectious risk to patients, is therefore on no account justified.

Although objective measurements may favor a particular system, they may not unfold their full potential because subjective factors, such as user-friendliness, may interfere substantially. In this study, the more time-efficient handling of systems B and C thus resulted in a preference toward these systems in the subjective ranking evaluation. System C was merely rated inferior to the other systems in terms of initial injector assembly, which is routine use in our institution and so forth. Thus, costs cannot be transferred from one institution to the other. Furthermore, cost expenditure arises mainly from the consumable material (i.e., syringes and tubes) and thus greatly depends on their expense. To ensure comparability and to avoid misinterpretation, relative cost declarations are preferable. On the basis of these assumptions for 30 examinations, the costs of system A are 8 times higher and those of system B are 45 times higher than the costs of system C. In other words, the use of system C saves 81% of costs in comparison with system A and 97% in comparison with system B. It has to be considered that costs for syringes in system B already include the contrast agent (prefilled syringes).

This study does have limitations. Subjective ranking of the different injection systems is influenced by the dependence of technicians on a particular system. Remarkably, system A was ranked inferior to systems B and C even though the involved technicians were more familiar with system A because of its routine use in our institution for many years. Therefore, a significant bias resulting from experience can be excluded. Future advancements in the construction of automatic injectors should also focus on hygienic aspects (e.g., special one-way valves and prefilled combination syringes for contrast agent and saline) for proper prevention of microbial contamination. In addition, prefilled combination syringes for contrast agent and saline could further accelerate the preparation of injection system B.

We conclude that double-syringe injectors used with disposable or prefilled contrast agent syringes, as well as roller pump injectors, ensure hygienic conditions and avoid the hazard of septic complications in clinical routine, especially in imaging of immunocompromised patients. However, time efficiency and handling are aspects in clear favor of prefilled and roller pump systems.

References
13. Flohr TG, Leng S, Yu L, et al. Dual-source spiral CT with pitch up to 3.2 and 75 ms temporal resolu-
19. Lee DH, Jung KY, Choi YH. Use of maximal sterile barrier precautions and/or antimicrobial-coated catheters to reduce the risk of central venous catheter-related bloodstream infection. Infect Control Hosp Epidemiol 2008; 29:947–950