



## Ultra-structural evaluation of needles and their role for comfort during subcutaneous drug administration

Avaliação ultraestrutural de agulhas e seu papel no conforto durante a administração subcutânea de medicamentos

Evaluación ultraestructural de agujas y su papel en el confort durante la administración subcutánea de fármacos

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### How to cite this article:

Pereira IB, Oliveira MMM, Ferreira PBP, Coutinho RP, Cameron LE, Porto IS. Ultra-structural evaluation of needles and their role for comfort during subcutaneous drug administration. Rev Esc Enferm USP. 2018;52:e03307. DOI: <http://dx.doi.org/10.1590/S1980-220X2017024003307>

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### ABSTRACT

**Objective:** To evaluate the morphology of hypodermic needle bevels after drug aspiration, and the perception of comfort caused by the change or not of needles between preparation and subcutaneous drug administration. **Method:** Experimental research carried out in two moments. Initially, hypodermic needles were analyzed by scanning electron microscopy, and then a pilot trial was conducted with the participants, which indicated the level of comfort perceived at the time of needle bevel penetration during subcutaneous administration. **Results:** Forty-one adult inpatients participated in the study. Although the needles presented a slight to significant morphological alteration when evaluated by ultramicroscopy, the participants in this study were not able to report significant sensory changes during their penetration in the two techniques used. **Conclusions:** The standardization of fixed needle syringes, or the use of a single needle for both the preparation and the subcutaneous drug administration should be considered as strategies to reduce the production of sharp-perforating residues, to decrease the cost per procedure, and to limit the risk of contamination of critical devices.

### DESCRIPTORS

Injections, Subcutaneous; Needles; Syringes; Evidence-Based Nursing; Patient Comfort.

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Received: 06/06/2017  
Approved: 11/13/2017

## INTRODUCTION

Among the different roles of nurses and other members of the nursing team in the hospital environment, the responsibility for administering medications represents one of the most important collaborative actions for modern nursing practice. This role requires specific technical-scientific knowledge for the storage, handling, preparation, administration, and disposal of the most diverse materials involved in the technique. In addition, nurses have, in most cases, the responsibility of properly training patients in self-administration of injections at home when required. Thus, nurses' daily practice has a direct impact on the experience of patients admitted to health facilities, and may be related to patient safety and compliance to the proposed drug therapies both in the hospital and at home.

Among the available routes, the advantages of administering drugs directly into the subcutaneous tissue are highlighted. This route involves a relatively simple technique that is less painful and less aggressive than the intramuscular or intravenous injection, and allows the patient autonomy through the possibility of self-medication at home. Several pathologies, such as diabetes, deep vein thrombosis<sup>(1)</sup>, palliative care<sup>(2)</sup>, and HIV or HCV virus infections<sup>(3-4)</sup> currently require frequent, sometimes *ad aeternum* use of subcutaneous injectable drugs. In other cases, this route has been considered as a very effective alternative for several therapies and, in some cases is the only viable option, as in the treatments that adopt peptides – insulins, immunoglobulins<sup>(5-7)</sup> – the oral administration of which would completely inactivate the active principles of the drugs.

Although “needle phobia” is a potentially complicating factor for the success of therapies with injections<sup>(8)</sup>, it is estimated that its prevalence is less than 25% in most studies dealing with this fear. An alternative to this would be the use of needle-free devices, which are not always readily available to the entire population, especially the most needy, due to their high cost. This is one explanation for the increasing use of the subcutaneous technique in the treatment of the most diverse pathologies.

Currently, two different techniques of subcutaneous administration of drugs are accepted by the most specialized nursing literature. The first one, called the “conventional technique”, recommends changing needles between the steps of preparation and administration itself. The advantage of this technique would guarantee the physical integrity of the bevel and, with this, easier insertion of the needle into the patient's skin, which would reduce the discomfort observed during the procedure. However, the undeniable problem of sharp-perforating injuries, especially among nursing professionals, has led manufacturers of these materials, already in line with guidelines from the World Health Organization (WHO), to develop devices with fixed needles or safety locks, which hamper or even prevent the change of needles, thus reducing their manipulation and the risk of accident.

A second technique has emerged from the need for nursing professional practice, and the advances observed in recent

years in the field of biomedical materials engineering. Such technique provides for the use of the same needle for both the preparation/aspiration, and the administration of drugs. In this case, using only one needle (fixed or not) reduces: (1) the cost of the procedure; (2) the risk of contamination (by reducing syringe/needle kit manipulation); (3) the production of sharp and perforating residues; and (4) the risk of accidental needle manual disconnection after the procedure (in fixed syringe/needle kits) is achieved.

Data from WHO in 2002 show that around two million accidents with sharp-perforating objects occur annually among healthcare professionals, and may account for 37.6% of cases of hepatitis B virus infection, 39% of cases of HCV (both represent 40% of all cases of viral hepatitis in the world), and 4.4% of cases of HIV infection (2.5% of the total) in health professionals. Recent studies point to even more alarming data, even after the adoption of specific devices for the disposal of sharp and perforating material, and the summary prohibition of needle recap<sup>(9)</sup>. The manuals and recommendations that deal with the techniques involving sharp and perforating objects are very clear and incisive in relation to the recommended procedures, in order to maintain the health professionals' integrity. However, sharps injuries are still a major health problem, especially for nursing professionals, who handle catheters and needles much more frequently than other professionals<sup>(10-11)</sup>.

Currently, several studies have already been conducted in an attempt to correlate: (1) the application of warm or cold compresses before and after the procedure<sup>(12)</sup>; (2) the bevel positioning<sup>(13)</sup>; (3) procedure time length<sup>(14)</sup>; (4) the volume administered<sup>(14)</sup>; (5) the needle insertion site<sup>(15)</sup>; and (6) the aspiration (after the introduction of the needle into the subcutaneous tissue)<sup>(16)</sup> to the perception of pain reported by the patient, the formation of bruising, and compliance to drug treatments.

However, a broad and exhaustive search of the main international databases (LILACS, IBECs, MEDLINE, Cochrane Library, SciELO, and CINAHL) using the terms “subcutaneous” and “needle” revealed, from more than 8,000 records, only one trial related to the impact of needle change on the perception of pain during subcutaneous drug administration<sup>(17)</sup>. In addition, the impact of needle change between aspiration and administration of subcutaneous heparin was assessed in one study<sup>(18)</sup> regarding bruising formation, but without contemplating the appearance of pain/discomfort.

Thus, this study aims to: (1) determine whether the aspiration of injectable drugs contained in ampoule vials and multi-dose vials is capable of generating important morphological changes in hypodermic needle bevels; and (2) assess whether needle thread impairment is responsible for an increase in the perception of discomfort by patients using medications by this route. Thus, this study seeks to discuss the impact of the introduction of syringes with fixed hypodermic needles in the treatment of diseases requiring frequent subcutaneous drug administration, for the practice of nursing and for the comfort of patients in the health services.

## METHOD

Trifacet hypodermic needles of four different gauges (0.25 x 6 mm, 0.3 x 8 mm, 0.3 x 13 mm, and 0.45 x 13 mm) underwent scanning electron microscopy after mimicking preparation/aspiration of injectable medications contained in ampoules or multi-dose vials. Only needles from a brand previously evaluated and approved by INMETRO (National Institute of Metrology, Quality and Technology, Brazil – *Instituto Nacional de Metrologia, Qualidade e Tecnologia*) were used in this study. Because there were no conflicts of interest, the manufacturer's name was kept confidential.

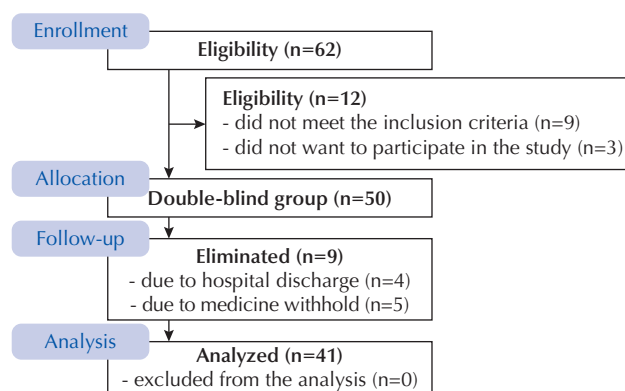
For the first experimental sample, the needles of the “1-time multi-dose vial” (n = 5) and “2-time multi-dose vial” (n = 5) groups were respectively introduced once and twice into the vials' rubber cap, whereas the needles from the “glass” group were used in glass ampoules (n = 5). The second experimental sample was obtained with the help of 15 nurses who agreed to participate anonymously in this study. Each nurse was instructed to aspirate the contents of a glass ampoule of sodium heparin (5,000 IU in 250 µL), as recommended by the nursing technique (trying to avoid touching the needles' bevel on the walls of the ampoules). None of the nurses had previous knowledge that the needles would be evaluated by scanning electron microscopy.

Then the plastic portions of the needles were removed from the metal segment and discarded. For the scanning electron microscopy trials, the needles were carefully fixed on an aluminum holder lined with carbon double-sided conductive tape, so as not to allow the bevels to contact the plate. The images were obtained under a Jeol 5310 microscope operating at 15 kV, and a work distance of 19 mm, with the aid of the Sem Afore® JEOL 3.0 Pro software with a resolution of 1024 x 768 pixels.

The double-blind pilot study was conducted with 41 adult patients admitted to a university hospital in the city of Rio de Janeiro (Brazil), who already had regular use of sodium heparin by the subcutaneous route. Patients with immunological impairment assessed by recently performed leukograms, or T-CD4+ lymphocytes, in the case of HIV patients, those decompensated, with any alteration of the level of consciousness and orientation assessed through physical examination and based on their reports, and patients with clinical diagnoses related to the alteration of pain perception, such as sensory-motor deficiency, peripheral vascular disease, and peripheral neuropathy were excluded.

Each patient received at least two doses of 5,000 IU of sodium heparin prepared with the two subcutaneous drug administration techniques currently accepted in the literature (“conventional technique” and “emerging technique” [see introduction], total n = 182 injections). All doses were given with a time interval of 8 and 12 hours, according to the medical prescriptions of the participants, by the same nurse, who respected the rotation of the application site indicated by the patient, with an administration rate of 1 mL every 10 seconds, angle of insertion of the needle of 90° (in skin fold performed with the non-dominant hand), without air in the needle lumen, without previous aspiration of the subcutaneous panniculus, and without application of cold before or after the procedure.

Following each injection, a comfort/discomfort Likert scale (very uncomfortable, uncomfortable, neutral, comfortable, and very comfortable) was immediately presented to each patient, who indicated which level was closest to that perceived during needle penetration (not during insertion of the liquid). The word “pain” was not used in order to avoid any induction of perception to study participants. Aseptic techniques were observed both in the preparation of the medications and in their administration. The needle-syringe kits were placed in containers suitable for the disposal of sharp and perforating materials. At the end of the pilot test, the data were tabulated and analyzed in pairs (“conventional technique” x “emerging technique”) with the aid of SPSS® software.



**Figure 1** – Schematic presentation of the process of recruitment and follow-up of the study participants.

The double-blind study of the perception of (dis)comfort reported during the technique of subcutaneous drug administration was conducted according to Resolution 466 of 2012 of the National Health Council (Ministry of Health), and approved by the Research Ethics Committee of Anna Nery School of Nursing, and São Francisco de Assis School Hospital, both part of the Universidade Federal do Rio de Janeiro, under registration no. 439.346 (CAAE 19112413.4.3001.5257) in October 2013. Following approval by the Ethics Committee, the participants were selected according to the inclusion and exclusion criteria described in the methodology, and signed the respective Informed Consent Term.

## RESULTS

Scanning electron microscopy images showed that, for needles of smaller sizes/gauges (0.25 x 6 mm and 0.25 x 8 mm), the passage of the bevels through the latex cap of the multi-dose vials, even twice (“2-time MDV” (multi-dose vials)), does not appear to be responsible for significant changes in its morphology. However, when contacted with the glass walls of the ampoules (“ampoule” sample), the bevels of two of the needles showed noticeable changes when compared to those of the control group needles. In this sense, the evaluation of hypodermic needles of different gauges is warranted, in which such alterations could be more easily perceived (Figure 2).

For the needles measuring 0.3 x 13 mm and 0.45 x 13 mm, more important changes were detected under all experimental conditions, which shows that a single introduction of the needle through the rubber of the multi-dose vial ("1T MDV") may be responsible for the morphological change in its bevel. A second introduction of the needles by the rubber cap of these vials appears to have intensified the morphological impairment observed in such bevels. In these needles, it was possible to observe the deviation of the bevel tip and even loss of the sample's wire ("2T MDV"), as indicated by the respective asterisks of Figure 2. As with the smaller gauges needles, noticeable morphological changes were also found on needles used for the preparation of heparin contained in glass vials ("ampoule").

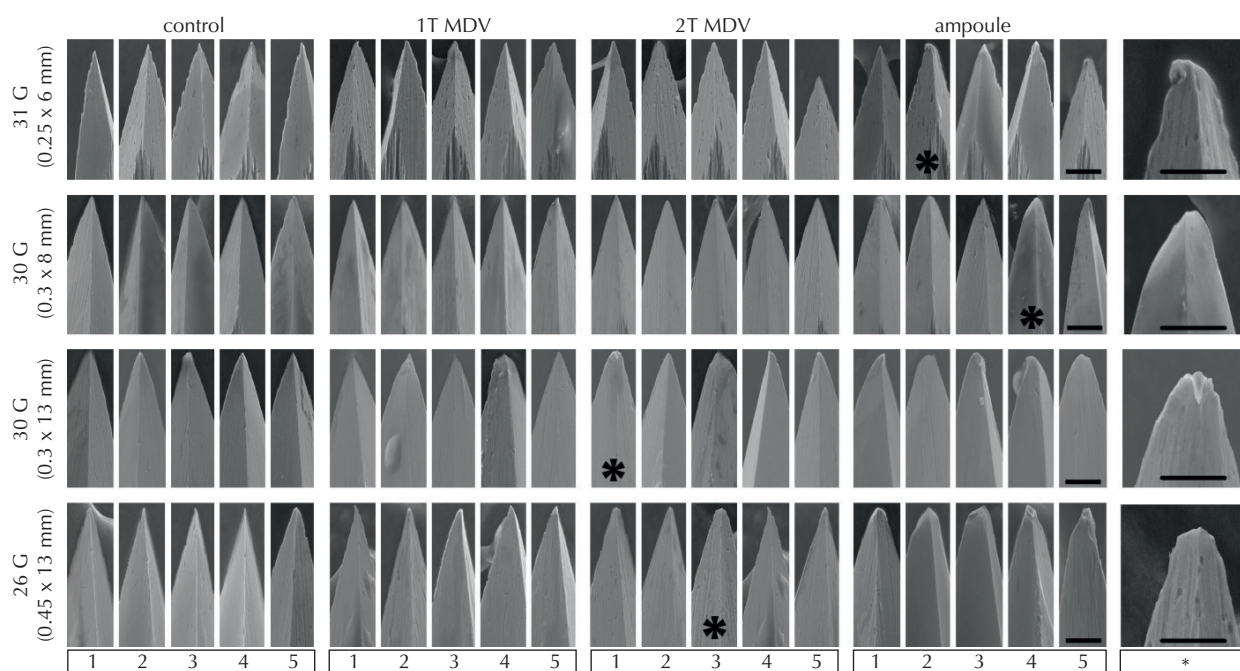
The results were compared to the ultrastructural analysis of unused needle bevels (control), n=5 for each variable. Asterisks represent the most noticeable changes to SEM (right column). The bars represent 100  $\mu$ m.

A similar result was obtained in the 15 samples prepared by the collaborating nurses in this study. In this group, it is possible to observe the deviation of the bevel of several needles, which could be related to the increase in patients' perception of discomfort during subcutaneous drug administration (Figure 3).

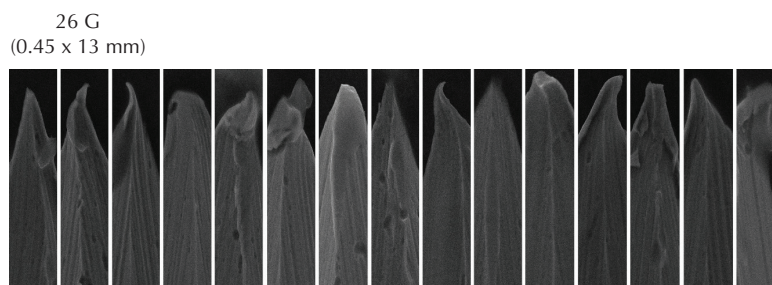
All needles presented considerable wire loss when analyzed by Scanning Electronic Microscopy (SEM); for details, see methodology. The bars represent 100  $\mu$ m.

The overall analysis of sensory perception of the study participants demonstrates that regardless of needle change between preparation and administration, the subcutaneous injection technique tends to be considered neutral or comfortable by the majority of the population (Figure 4). Only 11.54% of the injections were considered uncomfortable or very uncomfortable during the double-blind pilot trial.

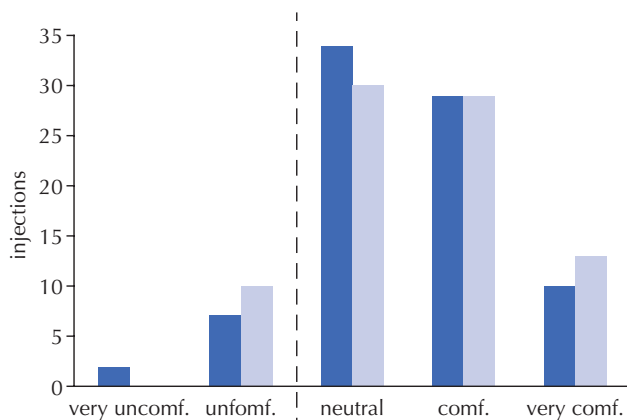
Most of the applications (88.46%, n=161) were considered neutral, comfortable, or very comfortable by the participants of this pilot study.



**Figure 2** – Scanning Electronic Microscopy (SEM) of four different hypodermic needles after preparation of the medication from the multi-dose vials (MDV) or glass ampoules.



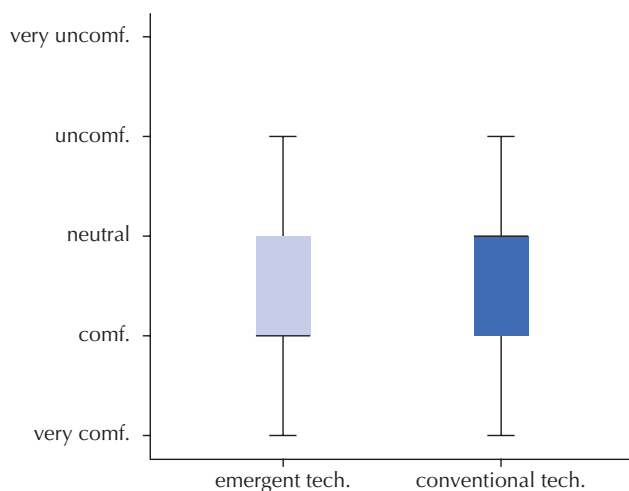
**Figure 3** – Scanning Electronic Microscopy of hypodermic needles (26 G – 0.45 x 13 mm) used by 15 different nurses for the preparation of drugs.



Legend: very uncomf. – very uncomfortable; uncomf. – uncomfortable; comf. – comfortable and very comf. – very comfortable.

**Figure 4** – Perception of comfort reported by the 41 participants of the double-blind trial during the technique of subcutaneous administration of a drug that is common to everybody.

The score median of (dis)comfort reported by the study participants during the use of the emerging subcutaneous drug administration technique was -1 on the adapted Likert scale (corresponding to the “comfort” point – standard deviation = 0.905) while the median score for the conventional technique was 0 on this same scale (corresponding to the “neutral” point – standard deviation = 0.905). The median statistical analysis of (dis)comfort intensity reported between the “emergent” and “conventional” techniques showed no significant difference in the Mann-Whitney U test ( $p = 0.622$ ), indicating that both techniques may be equally perceived by the participants of this study (Figure 5).



Legend: very uncomf. – very uncomfortable; uncomf. – uncomfortable; comf. – comfortable and very comf. – very comfortable.

**Figure 5** – Asymptotic significance of chi-square of total events (emergent and conventional techniques).

The unpaired analysis of the data obtained did not reveal, in most cases, a significant difference in the perception of the level of (dis)comfort reported by study patients during the double-blind trial.

## DISCUSSION

The evaluation of hypodermic needle bevels submitted to scanning electronic microscopy conducted in this study confirms the hypothesis that drug preparation is sufficient to cause perceptible morphological changes at needle tips. An *in vitro* study comparing trifacet and pentafacet hypodermic needles demonstrated that the bevel geometry has a direct relation with the strength necessary for the penetration of needles into an artificial substitute of human skin<sup>(19)</sup>. Thus, the theory that seems to thrive is that of needles change between preparation and subcutaneous drug administration, as a way of guaranteeing the morphology of the bevels, can have a positive influence on the perception of discomfort in patients who use drugs through this route. The presence and intensity of pain in response to needle change between the steps of drug preparation and administration were previously evaluated for intramuscularly administrable medications. In this randomized study (also with 50 participants), there was a significant difference in the perception of pain when comparing “conventional” and “emergent” techniques<sup>(20)</sup>. However, the same result could not be observed during a randomized trial in another study<sup>(17)</sup> involving subcutaneous administration of drugs. This work raises doubts regarding the possibility of comparing the data obtained with the two techniques of subcutaneous drug administration – “conventional” and “emergent” – because the trial was not blinded, the possible unconscious interference of the researcher in the results observed (13 x 0.45 mm and 12.7 x 0.4 mm), and the comparison of pain perception among different individuals (randomization).

Due to the subjective and personal nature of human sensory perception<sup>(21)</sup> and the negative impact that pain during injection drug administration may represent for compliance to treatments<sup>(22)</sup>, the double-blind pilot study conducted attempted to compare perceptions of comfort/discomfort in relation to the two techniques contemplated here (“conventional” and “emergent”) among the same individuals. After the data were paired, the statistical analysis of the results obtained in the trial resulted in poor and fair agreement between the scores attributed by the participants after the procedures performed with the “conventional” and “emergent” techniques (Kappa value 0.186 and 0.237; data not shown), pointing to the difficulty of correlation between the variables. In addition, in both sets of experiments (1 and 2), the p-value obtained with the Wilcoxon test for paired samples was above 5%. Thus, within the sample obtained during the pilot study, it was not possible to infer a correlation between the perception of discomfort and the techniques used to prepare the subcutaneous injections. These results are concordant with those observed in a previous study, which also found no significant relationship between the “conventional” and “emergent” techniques, and the perception of pain by the participants in that study<sup>(17)</sup>. Thus, it may be suggested that the perception of comfort/discomfort in these cases seems to be more related to the development of the technique by the nurse and to different intrinsic factors than by the use of needles whose bevels were damaged during drug preparation.

On the other hand, the low frequency of perceptible morphological changes in the bevels of hypodermic needles evaluated in this study, as observed in Figure 2, can warrant the difficulty of statistical correlation between the sensory perception of the participant and the technique used. In addition, the vast majority of participants in this pilot study evaluated the technique of subcutaneous drug administration as a neutral or even comfortable procedure, which may warrant and encourage the increasing use of this route for the most diverse pharmacological treatments. The positive role of comfort for compliance to insulin therapy, for example, has already been described in the literature<sup>(23)</sup>.

Finally, the slight morphological changes observed in this study on needles of smaller sizes (0.25 x 6 mm and 0.25 x 8 mm) may point to the standardization of the smaller needles during subcutaneous drug administration. This suggestion is also supported by a review<sup>(24)</sup>, which indicates a significant difference in the perception of pain between needles of smaller and larger sizes.

Although the data obtained in this study reaffirmed the results of the randomized trial previously conducted by another study<sup>(17)</sup> with 240 patients, the low sampling of this pilot study may be considered a limitation. Thus, new trials, preferably multicentric ones, and with a greater number of participants, should be considered.

## CONCLUSION

The data obtained in this study, in agreement with the results already available in the international literature, indicate that for the technique of subcutaneous injection of medications, the practice of using different needles in the preparation and administration steps does not offer a significant advantage for the perception of comfort/discomfort by the patient. These conclusions point to the possibility of standardization of the “emergent technique” to the detriment of the “conventional technique”, and are still in line with the growing need and tendency of evidence-based nursing practice.

The use of a single needle can represent several advantages for this procedure, both from the point of view of the patient and the health services, that is, lower cost for the purchase of spare needles; reduction of syringe manipulation and possible reduction of drug contamination risk; reduction of the generated sharp and perforating material disposal; and simplification of the technique, especially for the patients who perform it in their homes. Finally, the standardization of the “emergent technique” should not find resistance among nurses or in the international scientific community, considering recent studies and current guidelines, which already describe the technique of subcutaneous drug injection without the practice of needle change between the preparation and administration.

## RESUMO

**Objetivo:** Avaliar a morfologia de biséis de agulhas hipodérmicas após a aspiração de drogas e a percepção de conforto ocasionado pela troca ou não de agulhas entre preparo e administração de medicamentos pela via subcutânea. **Método:** Pesquisa experimental realizada em dois momentos. Inicialmente, agulhas hipodérmicas foram analisadas por microscopia eletrônica de varredura e, em seguida, um ensaio piloto foi conduzido com os participantes, que indicaram o nível de conforto percebido no momento da penetração dos biséis das agulhas durante a administração pela via subcutânea. **Resultados:** Participaram do estudo 41 pacientes adultos internados. Apesar de as agulhas terem apresentado de discreta a importante alteração morfológica, quando avaliadas por ultramicroscopia, os participantes deste estudo não foram capazes de relatar alterações sensoriais significativas durante a penetração destas nas duas técnicas adotadas. **Conclusões:** A padronização de seringas com agulhas fixas ou o uso de uma única agulha tanto para o preparo quanto para a administração de medicamentos pela via subcutânea devem ser considerados como estratégias para redução da produção de resíduos perfurocortantes, diminuição do custo por procedimento e limitação do risco de contaminação de dispositivos considerados críticos.

## DESCRITORES

Injeções Subcutâneas; Agulhas; Seringas; Enfermagem Baseada em Evidências; Conforto do Paciente.

## RESUMEN

**Objetivo:** Evaluar la morfología de biseles de agujas hipodérmicas luego de la aspiración de drogas y la percepción de confort ocasionado por el cambio de agujas entre la preparación y la administración de fármacos por la vía subcutánea. **Método:** Investigación experimental llevada a cabo en dos momentos. Inicialmente, agujas hipodérmicas fueron analizadas por microscopia electrónica de barrido y, a continuación, un ensayo piloto fue conducido con los participantes, quienes señalaron el nivel de confort percibido en el momento de la penetración de los biseles de las agujas durante la administración por la vía subcutánea. **Resultados:** Participaron en el estudio 41 pacientes adultos ingresados. A pesar de que las agujas hayan presentado de discreta a importante modificación morfológica, cuando evaluados por ultramicroscopia, los participantes de este estudio no fueron capaces de relatar modificaciones sensoriales significativas durante la penetración de esas en ambas técnicas adoptadas. **Conclusión:** La estandarización de jeringas con agujas fijas o el empleo de una sola aguja tanto para la preparación como la administración de fármacos por la vía subcutánea se deben considerar como estrategias para reducción de la producción de residuos punzocortantes, reducción del costo por procedimiento y limitación del riesgo de contaminación de dispositivos considerados críticos.

## DESCRIPTORES

Inyecciones Subcutâneas; Agujas; Jeringas; Enfermería Basada en la Evidencia; Comodidad del Paciente.

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### Financial support

*Conselho Nacional de Pesquisa e Desenvolvimento (CNPq), Ministério de Ciência e Tecnologia, Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) and Fundação Universitária José Bonifácio (FUJB).*



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