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## **Clinical practice recommendations for nurse-administered intramuscular injections in mental health: A modified Delphi study**

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## **Abstract**

**Aim:** To develop clinical practice recommendations for nurse-administered intramuscular injections in mental health.

**Background:** Intramuscular injection is the main route of long-acting injectable antipsychotics' administration that appear to improve the long-term prognosis of mental illness. Specific guidelines related to the nurse administration of intramuscular injections need to be updated and to explore not only the technical aspects of this procedure.

**Design:** A modified RAND/University of California Los Angeles (UCLA) appropriateness method Delphi study was conducted between October 2019 and September 2020.

**Methods:** A multidisciplinary steering committee conducted a literature review and developed a list of 96 recommendations. These recommendations were submitted in a two-round Delphi electronic survey to a panel of 49 experienced practicing nurses from five mental health hospitals in France. Each recommendation was rated for its appropriateness and applicability in clinical practice on a 9-point Likert scale. Consensus among nurses was evaluated. The steering committee discussed the results after each round and approved the final set of recommendations.

**Results:** A final set of 79 specific recommendations were accepted for their appropriateness and applicability in clinical practice. Recommendations were classified in five domains: legal and quality assurance aspects, nurse-patient relationship, hygiene, pharmacology, and injection technique.

**Conclusion:** The established recommendations placed patients at the heart of the decisions concerning the intramuscular injection and underlined the need for specific training programs. Future research should focus on the integration of these recommendations in clinical practice, by both before-and-after studies and regular assessments of professional practices with relevant indicators.

**Impact:** The recommendations developed for good nursing practices explored not only the technical aspects but integrated the nurse-patient relationship. These recommendations may impact usual practices of administration of long-acting injectable antipsychotics and most of them could be applied in many countries.

**No Patient or Public Contribution:** Due to the study design.

**Keywords:** Delphi consensus, Delphi technique, Intramuscular injections, Mental health, Nursing, Recommendations

## 1 INTRODUCTION

Nurses frequently administer intramuscular injections in mental health settings. Recent years have seen the development of second-generation, long-acting injectable antipsychotics (LAIAs) with pharmacological properties that appear to improve the long-term prognosis of mental illness such as schizophrenia. They have brought the practice of this nursing procedure back to the foreground in mental health (Correll et al., 2016; Ostuzzi et al., 2021; Preskorn, 2017). Moreover, intramuscular injection is the route of administration recommended for patients experiencing first psychotic episode (Abdel-Baki et al., 2022; Kane & Garcia-Ribera, 2009; Subotnik et al., 2015). The use of LAIAs in the maintenance treatment of bipolar disorders and schizoaffective disorders has raised interest to improve adherence and reduce the risk of relapse (Pacchiarotti et al., 2019). It also remains the preferred route for administering sedative treatments in patients with acute agitation (Battaglia, 2005).

Injection of LAIAs is a usual practice for nursing in mental health, however there are very few specific guidelines with no recent update (Borja & Galbraith, 2019; Cocoman & Murray, 2008; Wynaden et al., 2005, 2006). These guidelines often explored only the technical aspects of intramuscular injection. Moreover, they are not always followed, especially those related to the selection of the injection site and the use of the Z-track technique (Cocoman & Murray, 2008; Franks, 2004; Legrand et al., 2019). The interval between the publication date of these guidelines and their application in daily practice also appears long (Wynaden et al., 2015).

Beyond the technical aspects of intramuscular injections, the international guidelines or recommendations available do not explore questions related to the nurse-patient nursing relationship. Nonetheless, the activity of nursing care is characterized by the importance assigned to the nurse's relationship with patients, most especially in mental health as they have poor medication adherence. This caring relationship in mental health can appear difficult to state in formal terms.

The development of recommendations requires the consideration of all the conditions in which the procedure may be practiced. A study of the practices of the preparation and administration of intramuscular injections in mental health suggests that adherence to guidelines is significantly less frequent when the intramuscular injection is performed in an emergency situation (Legrand et al., 2019).

Finally, questions linked to the quality and safety of care are essential today in the management of all patients. No recommendations have yet, to our knowledge, integrated this aspect for intramuscular injections in mental health.

Based on available evidence, it is important to update recommendations for the technique of intramuscular injections in mental health. The questions related to the conditions of injection (emergency versus scheduled) must also be considered. The applicability in clinical practice of the recommendations must be taken into account to improve their acceptance by nurses.

Our objective was to develop clinical practice recommendations for administering intramuscular injections in mental health using a modified Delphi study, a method frequently applied both in mental health and in nursing research (Foth et al., 2016; Goodman, 1987; Jorm, 2015; Keeney, Hasson, & McKenna, 2001).

## **2 METHODS**

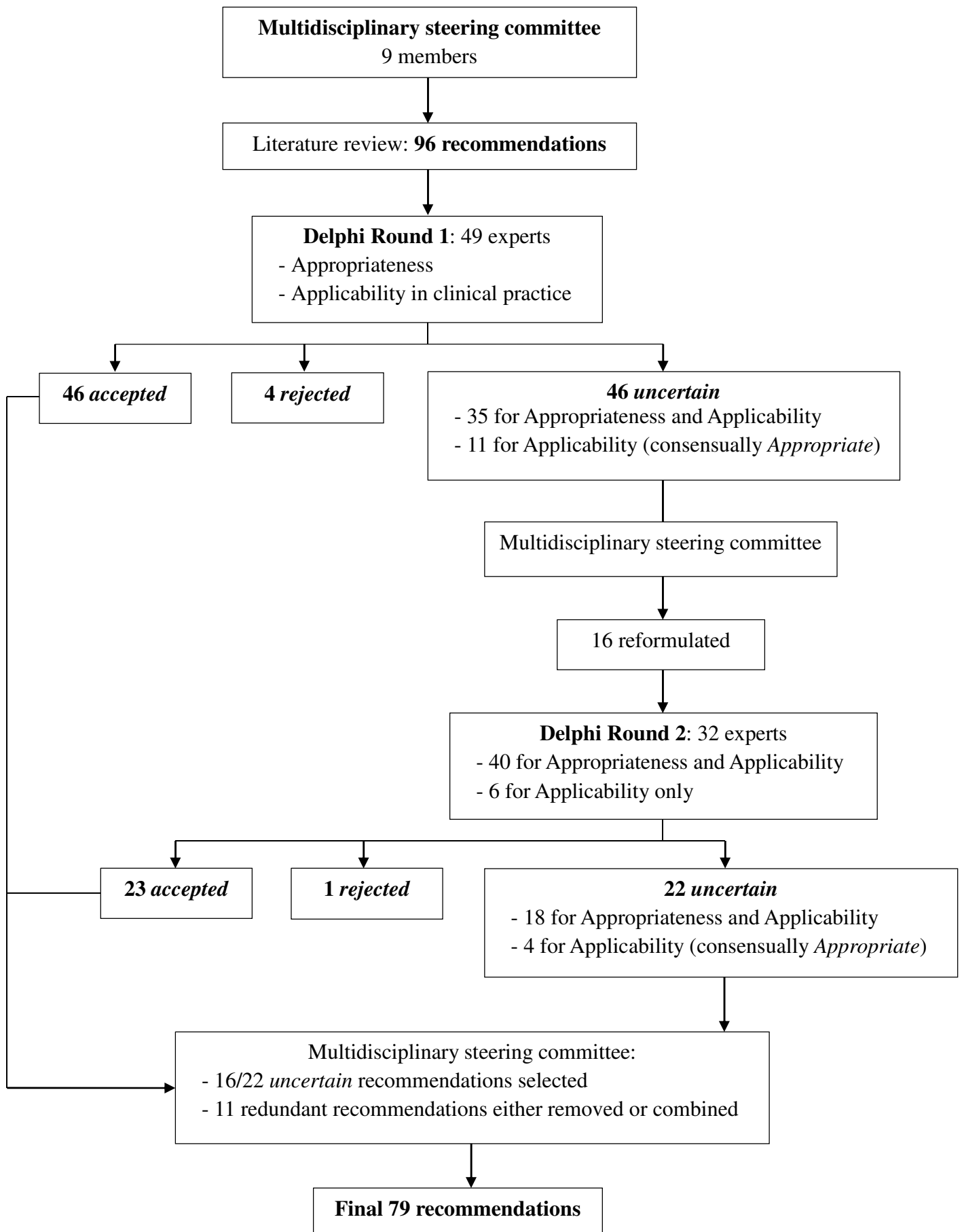
### **2.1 Design and setting**

A modified RAND/University of California Los Angeles (UCLA) appropriateness method Delphi study was used to develop a set of clinical practice recommendations between October 2019 and September 2020. The RAND/UCLA appropriateness method is an internationally recognized formal group consensus process. This method combines best available evidence with the collective judgment of informed persons considered experts to develop and classify items regarding their appropriateness (Fitch et al., 2001). This process comprised four phases (Figure 1). The first phase was the constitution of a multidisciplinary steering committee that reviewed the literature to identify recommendations in a second phase. The third phase consisted of two Delphi consensus rounds in which recommendations were rated by a panel of expert nurses. The Delphi method is a formalized technique for determining consensus agreement between experts in order to develop collective outcomes (Keeney et al., 2001; McKenna, 1994). The benefits of this approach are anonymity, iteration (allowing participants to change their opinions), not requiring the physical presence of the panellist, controlled feedback in which participants can see the group's previous responses, and the derivation of summary measures of agreement (Jones J & Hunter D, 1995; Keeney et al., 2001). In the fourth and last phase, the steering committee approved the final set of recommendations.

The RAND/UCLA appropriateness method was modified in our study by beginning the process with a set of carefully selected recommendations, the absence of physical meetings of the panel participants in the third phase and the possibility of discarding recommendations between the two rounds.

Methods and results are reported in line with the Guidance on Conducting and Reporting Delphi Studies (CREDES) (Jünger et al., 2017) (Supplementary Information 1).

**Figure 1:** Flow diagram of the modified RAND/UCLA appropriateness method Delphi study



## 2.2 Development of the initial draft of recommendations

A steering committee was established, made up of nine specialists in mental health, hospital hygiene, clinical pharmacy, anatomy, paramedical research, and public health. This multidisciplinary committee then reviewed the literature through December 2019. A search for all guidelines and reports on good clinical practices for intramuscular injections in mental health issued by learned societies in France or abroad, completed by a PubMed search, was conducted. References were selected independently by an expert in each of these domains: mental health, hospital hygiene, anatomy, clinical pharmacy, the nurse-patient relationship, pain, massage, and pressure. We identified 171 references and retained 63 that were pertinent to use as a basis for these good practice recommendations.

Then, during face-to-face and videoconference meetings, completed by e-mail exchanges, the steering committee formulated 96 recommendations, sought to clarify the wording of each one, and drafted the Delphi questionnaire. The web-based questionnaire and instructions were pretested on a sample of 10 nurses for face validity, as recommended (Keeney et al., 2001).

## 2.3 Delphi rounds

### 2.3.1 Panel of experts

The recommendations formulated by the steering committee were presented for rating in a two-round Delphi study. To compose the panel of experts, the steering committee first asked supervisors at five mental hospitals in France for a list of nurses experienced in intramuscular injections that have given their informed consent to participate. They received a cover letter by email explaining the study in detail and the uniform resource locator (URL) of the electronic questionnaire. They were informed that completion of the first round (round 1) questionnaire would indicate their willingness to participate in the follow-up second round of the Delphi study (round 2). Only participants who reported performing a number of intramuscular injections per week greater than the median of the distribution among responses of round 1 were retained as "experts" and received a link to the second round electronic questionnaire for completion. The participants received no financial or other compensation.

Round 1 data were collected from February 4 through March 13, 2020, and round 2 data from June 6 through July 17, 2020. For each round, a reminder email was sent two weeks after the initial email with the links to the questionnaire.

### 2.3.2 Data collection

During the two rounds, the panel of experts was invited to evaluate individually and independently each recommendation for its appropriateness and its applicability in clinical practice on a 9-point Likert scale from 1 to 9 (1 = totally inappropriate or totally inapplicable, 9 = totally appropriate or totally applicable, 5 = no opinion or indecision). The experts were also invited to provide comments to clarify their answers.

For round 2, each panel member received descriptive statistics (distribution of the panel's responses) for each recommendation rated in round 1 (Murphy et al., 1998). They were encouraged to reconsider their original responses taking into account the answers of the panel. Each participant had to score the recommendations that had not been accepted in the first round on the same 9-point Likert scale.

The steering committee received the detailed results and discussed them in a face-to-face meeting after each round. After they considered the experts' comments from round 1, the committee could reformulate recommendations to make them more comprehensive or more reflective of use in clinical practice. Modified recommendations were resubmitted to the expert panel in round 2 for further evaluation. After round 2, the steering committee was nonetheless authorized to include recommendations that the experts had not retained but which the committee judged important on the basis of its international literature review. The steering committee approved the final set of recommendations during their last plenary meeting.

### 2.3.3 Data analysis

Descriptive statistics were used to characterize the distribution of ratings for the two rounds: frequencies and percentages of each score, frequencies and percentages in the lowest tertile (between 1 and 3), frequencies and percentages in the upper tertile (between 7 and 9) and the median score.

Determination of consensus and judgment of recommendations followed the RAND/UCLA method (Fitch et al., 2001). The median was used to measure the central tendency of the distribution for each recommendation's rating, to judge it. A recommendation with a median score of 7-9 was judged *appropriate* or *applicable* in clinical practice. A recommendation with a median score of 1-3 was judged *inappropriate* or *inapplicable*. To evaluate consensus between experts (that is, the experts' agreement with each other), a continuous statistical measure of dispersion among individual scores was used: the Disagreement Index. We adapted the Rand Working Group definition and defined the Disagreement Index as the 10%-90% inter-percentile range (IPR) divided by the inter-percentile range adjusted for symmetry (IPRAS) (Fitch et al., 2001). In the RAND method, a Disagreement Index superior to 1 indicates lack of consensus or disagreement (high score dispersion with the IPRAS



smaller than the IPR), and a Disagreement Index less than 1 indicates consensus or agreement between experts (low dispersion of scores, with the IPRAS larger than the IPR).

Recommendations consensually judged both *appropriate* and *applicable* were *accepted*, while those consensually found *inappropriate* were *rejected* and thus subsequently excluded. Recommendations with a median score ranging between 3.5 and 6.5 or scored with disagreement were considered *uncertain*. Based on the findings of round 1, recommendations judged *uncertain* and/or reformulated were resubmitted for further evaluation and discussion in the second rating round both for appropriateness and applicability in clinical practice. Recommendations judged consensually *appropriate* but *uncertain* for applicability in clinical practice were resubmitted in the second round only for applicability.

The statistical analysis was performed with SAS software (version 9.4, SAS Institute, Cary, NC, 2002-2012).

## 2.4 Ethical considerations

No ethics approval was needed for our study, given that no personal data regarding participant were collected for the purposes of the present study. Under French law, no ethics committee is required as no personal data were registered (this study is not part of the research categories covered by the law Jardé - Décret n°2017-884, 9 may 2017). All nurses participating in the two-round of Delphi were informed about the study and gave their consent to participate when they replied to the first round. Throughout the data analysis, the anonymity of the expert nurses was guaranteed.

## 3 RESULTS

### 3.1 Professional characteristics of expert panel

Overall, of the 96 nurses recommended, we obtained email addresses for 91, and 89 completed the round 1 questionnaire for a response rate of 98%. Among them 82 reported the number of intramuscular injections they administered on average each week: a mean of 3.9 (SD 7.4) with a median of 2 (IQR 1-3). Accordingly, the 49 nurses who reported performing two or more intramuscular injections weekly were selected as the experts for the Delphi study. Among them, nine worked in a day hospital, 19 full-time in a care unit, 26 provided home care and five worked both in a day hospital or full-time care unit and provided home care. On average, they had 15.9 years (SD 9.9) of professional experience, and 69.4% had been working for at least ten years. They administered a mean of 5.9 (SD 9.0) intramuscular injections weekly, for a median of 3 (IQR 2-5).

Round 2 was completed by 32 of the 49 nurses from round 1 (65%), four working in a day hospital, 14 in a care unit full time, 13 provided home care and one both in day hospital and provided home

care. Their mean professional experience was 14.6 years (SD 9.1) and 65.6% had been working for ten years and more. They performed a mean of 5.5 (SD 7.9) intramuscular injections weekly, with a median of 3 (IQR 2-5).

### 3.2 Delphi consensus rounds

The Delphi process began with 96 preliminary recommendations rated for appropriateness and applicability. Figure 1 presents the flow chart of their selection.

After round 1, 46 recommendations were *accepted* (Table 1), 4 *rejected* (Table 2), 11 consensually rated *appropriate* but *uncertain* about their applicability (Table 1), and 35 judged *uncertain* both for appropriateness and applicability (Table 1). The 46 non-accepted recommendations were proposed in round 2 for further evaluation. Among them, 16 were slightly reformulated based on the experts' comments.

In round 2, 40 recommendations were proposed to the experts for appropriateness and applicability and 6 for applicability only. Twenty-three were *accepted* (Table 1), 1 *rejected* (Table 2), 4 consensually rated *appropriate* but *uncertain* about their applicability (Table 1), and 18 rated *uncertain* both for appropriateness and applicability (Table 1).

A synthesis of the two rounds of ratings was discussed by the steering committee during a plenary meeting in September 2020. Among the recommendations that had not been accepted, the steering committee considered 16 highly important and included them in the final set of recommendations (Table 1). Eleven recommendations with similar meanings were considered redundant and were either removed or combined.

Finally, a set of 79 recommendations was established and classified chronologically by domain: legal and quality assurance aspects (25 recommendations), nurse-patient relationship (16 recommendations), hygiene (16 recommendations), pharmacology (seven recommendations), and injection technique (15 recommendations) (Table 3).

**Table 1:** Recommendations not *rejected* classified by domain and their rating scores during the two-round Delphi study

	Round 1			Round 2 <sup>a</sup>		
	Appropriateness	Applicability in clinical practice		Appropriateness	Applicability in clinical practice	
Recommendations	Median score <sup>b</sup> (DI <sup>c</sup> )	Median score <sup>b</sup> (DI <sup>c</sup> )	Accepted, Uncertain <sup>d</sup>	Median score <sup>b</sup> (DI <sup>c</sup> )	Median score <sup>b</sup> (DI <sup>c</sup> )	Accepted, Uncertain <sup>d</sup>
<b>Legal and quality assurance aspects</b>						
1. It is recommended that nurses administering intramuscular injections follow specific continuing medical education (in addition to their initial training) in these procedures. <sup>e</sup>	7 (3.40)	5 (2.26)	Uncertain	7 (0.75)	6 (1.61)	Uncertain
2. It is recommended that the patient's informed consent be systematically obtained before the start of any intramuscular injection procedure. <sup>f</sup>	9 (0.75)	7 (1.09)	Uncertain	9 (0.29)	9 (0.75)	Accepted
3. It is recommended to verify the patient's informed consent before each new injection (except in emergencies).	9 (1.09)	8 (1.09)	Uncertain	9 (0.29)	8 (0.29)	Accepted
4. In an emergency, it is recommended to attempt by any means to obtain the patient's informed consent. <sup>g</sup>	6 (3.40)	3 (2.26)	Uncertain	7 (1.56)	4 (1.61)	Uncertain
5. Patients can withdraw their consent at any time.	9 (0.75)	8.5 (1.56)	Uncertain	-	9 (0.61)	Accepted
6. It is recommended that the patient be informed about the adverse effects associated with the procedure.	9 (0.29)	8 (0.75)	Accepted	-	-	-
7. It is recommended to avoid intramuscular injections in patients receiving anticoagulant treatment or presenting a coagulation disorder. <sup>f</sup>	9 (0.75)	9 (1.09)	Uncertain	9 (0.75)	8 (0.75)	Accepted
8. It is recommended that the file of patients receiving anticoagulant treatment be systematically updated to note this treatment.	9 (0.13)	9 (0.29)	Accepted	-	-	-

9. It is recommended that no injection ever be made into a body area containing osteosynthesis material or a prosthesis.	9 (0.75)	9 (0.75)	Accepted	-	-	-
10. It is recommended that the absence of any osteosynthesis material or prosthesis in the area be verified before any injection.	9 (0.49)	9 (0.75)	Accepted	-	-	-
11'. It is recommended that the patient's BMI (body mass index) be assessed regularly during his or her management. <sup>h</sup>	9 (0.29)	9 (0.75)	Accepted	-	-	-
11''. It is recommended that the patient's BMI (body mass index) be assessed before each new intramuscular injection. <sup>f, h</sup>	6 (3.40)	5 (3.40)	Uncertain	9 (0.49)	8 (0.75)	Accepted
12. It is recommended that needle supplied by pharmaceutical laboratories and available in injection kits be used in priority.	9 (0.13)	9 (0.29)	Accepted	-	-	-
13. Use of a needle adapted to the patient's morphology is recommended.	9 (0)	9 (0.23)	Accepted	-	-	-
14. If the patient's BMI is less than 30 kg/m <sup>2</sup> , use of a standard size needle, that is, 21G/38 mm, is recommended.	9 (2.26)	8 (1.09)	Uncertain	8 (0.75)	8 (0.75)	Accepted
15. If the patient's BMI is greater than 30 kg/m <sup>2</sup> , use of a long needle, that is, 21G/50 mm, is recommended.	9 (0.75)	8 (1.09)	Uncertain	-	8 (0.49)	Accepted
16. It is recommended that the psychiatrist's prescription be verified before the intramuscular injection is prepared.	9 (0)	9 (0.29)	Accepted	-	-	-
17. It is recommended that no injection ever be made into an area with any cutaneous problem (skin lesion, infection, etc.).	9 (0.13)	9 (0.29)	Accepted	-	-	-
18. When using irritating products, following the manufacturer's leaflet for its preparation and recomposition is recommended.	9 (0)	9 (0)	Accepted	-	-	-
19. Immediate monitoring is recommended after an intramuscular injection to check for the development of a hematoma. <sup>g</sup>	5 (3.40)	5 (3.40)	Uncertain	7 (1.09)	7 (2.26)	Uncertain
20. It is recommended that the patient's informed consent be	9 (0.75)	7.5 (1.56)	Uncertain	-	7 (0.49)	Accepted

documented in their file (potential difficulties must also be documented).

21. It is recommended that documentation that a patient was informed of the potential adverse effects of the product be noted in his or her file.	7 (1.56)	6 (1.56)	Uncertain	8 (0.49)	7 (0.75)	Accepted
22. The date, time, and type of injection must be documented in the patient's file.	9 (0)	9 (0)	Accepted	-	-	-
23. It is also recommended to document the date of the next scheduled intramuscular injection in the file.	9 (0)	9 (0)	Accepted	-	-	-
24. It is recommended that the patient be informed of the date of the next intramuscular injection.	9 (0)	9 (0)	Accepted	-	-	-
25. It is recommended that the patient be monitored in the days following an intramuscular injections to check for hematoma, an infection, and pain. <sup>g</sup>	8 (3.40)	6 (3.40)	Uncertain	8 (3.40)	7 (3.40)	Uncertain

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**Nurse-patient relationship**

26. It is recommended that relationship continuity (that is, limiting the fungibility of nurses) be maintained throughout the patient's care. <sup>e, f</sup>	8 (1.56)	5 (2.26)	Uncertain	8 (0.49)	6 (1.56)	Uncertain
27. It is recommended that patients be supported throughout the procedure (before, during, and after injection) to help attenuate their negative feelings.	9 (0.13)	9 (0.49)	Accepted	-	-	-
28. It is recommended before, during, and in the immediate follow-up of intramuscular injection, that opportunities for touch and/or physical contact be assessed as a means of diverting situational anxiety. <sup>f, g</sup>	6 (3.40)	5 (3.40)	Uncertain	6 (1.09)	6 (1.56)	Uncertain

29. Consideration of the effects of reassurance and the social representations associated with the administration of a long-acting intramuscular treatment is recommended.	9 (0.49)	8 (0.75)	Accepted	-	-	-
30. Verifying the utility of preparing the product to be injected in the patient's presence is recommended. <sup>f, g</sup>	8 (1.09)	8 (2.26)	Uncertain	8 (1.56)	7 (1.56)	Uncertain
31. It is recommended that the time spent preparing for the intramuscular injection procedure be used as relational support with the objective of transmitting to the patient the necessary information about the clinical procedure and providing education about the treatment. <sup>f</sup>	9 (3.40)	8 (3.40)	Uncertain	9 (0.75)	8 (0.75)	Accepted
32. After the patient has been informed about the factors involved in selecting an intramuscular injection site, it is recommended to favor his or her choice of site.	9 (0.29)	9 (0.75)	Accepted	-	-	-
33. Giving priority to the patient's choice for the environment, injection site, and related rituals is recommended.	9 (0.13)	7 (0.75)	Accepted	-	-	-
34. It is recommended that the professional who prepares the injection be the one to administer it.	9 (0)	9 (0.13)	Accepted	-	-	-
35. In emergencies, however, it is recommended that a professional leave the physical management of the situation to prepare and administer the intramuscular injection in less constrained conditions.	9 (0.29)	8 (0.75)	Accepted	-	-	-
36. It is recommended that the patient's privacy be respected.	9 (0)	9 (0.29)	Accepted	-	-	-
37. In emergencies, re-proposing an oral treatment is recommended after observing the positive impact (patient's awareness) of announcing that an injectable treatment will be used.	9 (0.75)	8 (1.09)	Uncertain	-	8 (0.75)	Accepted

38. It is recommended that techniques be used before an injection to reduce the pain at the moment of the injection. <sup>e, f</sup>	7 (1.56)	5 (2.26)	Uncertain	7 (0.75)	6 (1.56)	Uncertain
39. If a doctor's prescription or protocol for it exists, offering patients an anesthetic patch or cream is recommended before the intramuscular injection to limit its pain. <sup>f</sup>	9 (0.75)	5 (3.40)	Uncertain	9 (0.75)	8 (0.75)	Accepted
40. Diverting their attention at the moment of the intramuscular injection is recommended to limit the pain. <sup>f</sup>	9 (1.56)	8 (1.56)	Uncertain	8 (0.75)	8 (0.75)	Accepted
41. It is recommended that the patient's feelings and experience of the injection be assessed just after its administration.	9 (0.13)	9 (0.29)	Accepted	-	-	-

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### Pharmacology

42. Verification that the patient is not taking any anticoagulant treatment is recommended before each new intramuscular injection.	9 (0.13)	9 (1.09)	Uncertain	-	8 (0.49)	Accepted
43. It is recommended that products be injected at room temperature.	9 (0.29)	9 (0.49)	Accepted	-	-	-
44. It is recommended that the decision of the speed of administration take into account the type of product (aqueous or oily solution) and the patient's muscle tone.	9 (0.29)	9 (0.29)	Accepted	-	-	-
45. It is recommended that the product be injected slowly to limit pain (speed less than 1 ml per 10 seconds).	9 (0.29)	9 (0.49)	Accepted	-	-	-
46. It is recommended not to massage the area after the injection. <sup>g</sup>	8.5 (3.40)	9 (2.26)	Uncertain	9 (1.56)	9 (1.09)	Uncertain
47. It is recommended not to massage the area after an injection of olanzapine pamoate.	8 (0.75)	8 (0.75)	Accepted	-	-	-
48. It is recommended not to perform a local massage after an intramuscular injection because of the pharmacokinetic modifications it may induce, especially the risk of a post-injection	5 (0.75)	5 (0.75)	Uncertain	6 (1.56)	5 (1.56)	Uncertain

sedation syndrome. <sup>g</sup>

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## Hygiene

49. Washing one's hands with a mild soap or rubbing them together with an aqueous alcohol solution is recommended before administering an intramuscular injection. <sup>f</sup>	9 (0.75)	9 (1.09)	Uncertain	9 (0.13)	9 (0.29)	Accepted
50. It is recommended not to wear (nonsterile) gloves to prepare an intramuscular injection unless specifically recommended by the pharmaceutical manufacturer.	9 (3.40)	9 (3.40)	Uncertain	9 (0.75)	9 (0.75)	Accepted
51. It is recommended that sterile single-use material (syringe and needle) be used to administer intramuscular injections.	9 (0)	9 (0)	Accepted	-	-	-
52. Disinfecting the vial opening is recommended before removing the product from it to administer or reconstitute it.	9 (0.13)	9 (0.13)	Accepted	-	-	-
53. It is recommended that the needle be changed between the syringe-filling stage and the injection stage.	9 (0)	9 (0.13)	Accepted	-	-	-
54. If the injection site is visibly soiled, it is recommended that it be cleaned with mild soap, rinsed, and disinfected.	9 (0.49)	9 (2.26)	Uncertain	-	8 (0.75)	Accepted
55. It is recommended that the injection site be disinfected even if it is visibly clean.	9 (0)	9 (0)	Accepted	-	-	-
56. It is recommended that an alcohol antiseptic be used when the injection site is visibly clean.	9 (0.13)	9 (0.13)	Accepted	-	-	-
57. In emergencies, it is recommended that the injection site be disinfected a minima if it is visibly soiled. <sup>f</sup>	9 (3.40)	9 (3.40)	Uncertain	9 (0.75)	8 (0.75)	Accepted
58. When the injection site is visibly clean, it is recommended that the antiseptic be applied circularly and centrifugally.	9 (0.13)	9 (0.13)	Accepted	-	-	-
59. After disinfecting the injection site, it is recommended to wait	9 (0.75)	9 (0.75)	Accepted	-	-	-



for it to dry before administering the injection.

60. Disinfecting one's hands with an aqueous alcohol solution is recommended before administering an intramuscular injection.	9 (0)	9 (0)	Accepted	-	-	-
61. It is recommended that nonsterile gloves be worn before the administration of an intramuscular injection in case of risk of exposure to blood. <sup>f</sup>	9 (3.40)	9 (3.40)	Uncertain	9 (0.13)	9 (0.13)	Accepted
62. It is recommended that the needle then be disposed of in a container safe for pointed/cutting/sharp objects.	9 (0)	9 (0)	Accepted	-	-	-
63. It is recommended that a bandage be placed over the injection area in the case of blood return or reflux to the injection site.	9 (0.13)	9 (0.13)	Accepted	-	-	-
64'. Washing one's hands with a mild soap is recommended after administering an intramuscular injection. <sup>h</sup>	9 (0.29)	9 (0.75)	Accepted	-	-	-
64''. Disinfecting one's hands with an aqueous alcohol solution is recommended after administering an intramuscular injection. <sup>h</sup>	9 (0)	9 (0)	Accepted	-	-	-

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### **Injection technique**

65. It is recommended that the injection site be adapted to the patient's profile (sex and BMI).	9 (0.75)	8 (0.75)	Accepted	-	-	-
66. It is recommended that the injections be administered, in descending order of priority, in the gluteal, the vastus lateralis, and finally the deltoid muscle. <sup>e</sup>	5 (3.40)	5 (3.40)	Uncertain	7 (0.75)	6 (0.75)	Uncertain
67. It is recommended that patients with obesity (BMI $\geq$ 30 kg/m <sup>2</sup> ) receive intramuscular injections in the gluteus medius (ventrogluteal site). <sup>g</sup>	5 (1.56)	5 (1.56)	Uncertain	5 (0.75)	5 (0.75)	Uncertain
68'. For men with a BMI < 30 kg/m <sup>2</sup> , injections into the dorsogluteal area are recommended. <sup>h</sup>	7 (1.09)	6 (1.09)	Uncertain	8 (0.75)	7 (0.75)	Accepted

68". For women with a BMI < 30 kg/m <sup>2</sup> , injections into the dorsogluteal area are recommended. <sup>h</sup>	7 (1.56)	6 (1.56)	Uncertain	8 (0.75)	7 (0.75)	Accepted
69. The deltoid site is recommended for the initiation of paliperidone palmitate treatment (loading dose).	9 (0.91)	9 (0.91)	Accepted	-	-	-
70. It is recommended that the injection site be adapted to the doses (or volumes) to be administered to the patient.	9 (2.26)	8 (2.26)	Uncertain	8 (0.75)	8 (0.75)	Accepted
71. It is recommended that the thickness of the subcutaneous tissue be assessed before an intramuscular injection to help choose the site and the needle length.	9 (0.29)	9 (0.75)	Accepted	-	-	-
72. Alternating the deltoid and gluteal sites during the maintenance phase of treatment is recommended. <sup>f</sup>	8.5 (0.75)	6 (0.75)	Uncertain	8 (0.75)	7 (0.75)	Accepted
73. It is recommended that the superolateral quadrant be chosen for intramuscular injections in dorsogluteal area to limit the risk of sciatic nerve injury.	9 (0)	9 (0)	Accepted	-	-	-
74. It is recommended that intramuscular injections into the deltoid be administered with the patient in a seated position, elbow to body.	9 (0.29)	9 (0.29)	Accepted	-	-	-
75. It is recommended that, before the injection, manual pressure be applied to the area to promote muscle relaxation and reduce pain at the moment the injection is administered. <sup>g</sup>	5 (3.40)	5 (3.40)	Uncertain	6 (0.75)	5 (0.75)	Uncertain
76. It is recommended that the Z-track technique be used for intramuscular injections to limit the risk of hematoma. <sup>g</sup>	5 (1.61)	5 (0.65)	Uncertain	5 (0.65)	5 (0.75)	Uncertain
77. It is recommended that the Z-track technique be used for intramuscular injections to limit post-injection pain. <sup>g</sup>	5 (0.75)	5 (0.75)	Uncertain	5 (0.75)	5 (0.75)	Uncertain
78. It is recommended that the Z-track technique be used for intramuscular injections to limit the leakage/dispersion of the	5 (0.75)	5 (0.75)	Uncertain	5 (0.75)	5 (0.75)	Uncertain

product injected.<sup>g</sup>

79. Once the needle is in place, its aspiration is recommended before administration to avoid injection into the vessels.	9 (0)	9 (0)	Accepted	-	-	-
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<sup>a</sup> A recommendation judged *uncertain* and/or reformulated in round 1 was resubmitted in round 2. There are no results for round 2 when the recommendation was *accepted* in round 1.

<sup>b</sup> Each recommendation was rated on a 9-point Likert scale where 1 = totally inappropriate or totally inapplicable in clinical practice and 9 = totally appropriate or totally applicable in clinical practice.

<sup>c</sup> DI: Disagreement Index

<sup>d</sup> A recommendation consensually judged *appropriate* and *applicable* was *accepted* (median score of 7-9 and DI<1). A recommendation with a median score of 3.5-6.5 or scored non-consensually (DI>1) was considered *uncertain*.

<sup>e</sup> Recommendations consensually judged *appropriate* but *uncertain* for applicability in clinical practice on round 2 and retained by the steering committee on the basis of international literature review.

<sup>f</sup> Recommendations could be reformulated after round 1 taking into account experts' comments and then resubmitted in round 2. The modified recommendation could be found in Table 3.

<sup>g</sup> Recommendations judged *uncertain* on round 2 and retained by the steering committee on the basis of international literature review.

<sup>h</sup> Recommendations combined in one.

**Table 2:** Recommendations *rejected* during the two-round Delphi study and their rating scores

	Round 1		Round 2 <sup>a</sup>			
	Appropriateness	Applicability in clinical practice	Appropriateness	Applicability in clinical practice	Appropriateness	Applicability in clinical practice
Recommendations	Median score <sup>b</sup> (DI <sup>c</sup> )	Median score <sup>b</sup> (DI <sup>c</sup> )	Rejected, Uncertain <sup>d</sup>	Median score <sup>b</sup> (DI <sup>c</sup> )	Median score <sup>b</sup> (DI <sup>c</sup> )	Rejected, Uncertain <sup>d</sup>
It is recommended that intramuscular injections not be administered to patients receiving anticoagulant treatment or presenting a coagulation disorder.	1 (0.75)	2 (0.75)	Rejected	-	-	-
It is recommended to disinfect the injection site only if the patient is immunosuppressed.	1 (0.13)	1 (3.40)	Rejected	-	-	-
It is recommended not to aspirate before the injection.	1 (0.75)	1 (0.75)	Rejected	-	-	-
It is recommended that the product be injected rapidly to limit pain (speed more than 1 ml per 10 seconds).	1 (0.75)	1 (1.56)	Rejected	-	-	-
It is recommended to massage the area after injection except for injections of olanzapine pamoate.	5 (2.26)	5 (2.26)	Uncertain	1 (0.75)	2 (1.56)	Rejected

<sup>a</sup> A recommendation judged *uncertain* in round 1 was resubmitted in round 2. There are no results for round 2 when the recommendation was *rejected* in round 1.

<sup>b</sup> Each recommendation was rated on a 9-point Likert scale where 1 = totally inappropriate or totally inapplicable in clinical practice and 9 = totally appropriate or totally applicable in clinical practice.

<sup>c</sup> DI: Disagreement Index

<sup>d</sup> A recommendation consensually judged *inappropriate* was *rejected* (median score of 1-3 and DI<1). A recommendation with a median score of 3.5-6.5 or scored non-consensually (DI>1) was considered *uncertain*.

**Table 3:** Final set of clinical practice recommendations for nurse-administered intramuscular injections in mental health

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**Legal and quality assurance aspects**

1. It is recommended that nurses administering intramuscular injections follow specific continuing medical education (in addition to their initial training) in these procedures.
2. It is recommended that the patient's informed consent be systematically obtained before the start of any intramuscular injection procedure (except in emergencies).
3. It is recommended to verify the patient's informed consent before each new injection (except in emergencies).
4. In an emergency, it is recommended to attempt by any means to obtain the patient's informed consent.
5. Patients can withdraw their consent at any time.
6. It is recommended that the patient be informed about the adverse effects associated with the procedure.
7. It is recommended that intramuscular injections not be administered to patients receiving anticoagulant treatment or presenting a coagulation disorder.
8. It is recommended that the file of patients receiving anticoagulant treatment be systematically updated to note this treatment.
9. It is recommended that no injection ever be made into a body area containing osteosynthesis material or a prosthesis.
10. It is recommended that the absence of any osteosynthesis material or prosthesis in the area be verified before any injection.
11. It is recommended that the patient's BMI (body mass index) be assessed regularly during his or her management (at least twice a year).
12. It is recommended that needle supplied by pharmaceutical laboratories and available in injection kits be used in priority.
13. Use of a needle adapted to the patient's morphology is recommended.
14. If the patient's BMI is less than 30 kg/m<sup>2</sup>, use of a standard size needle, that is, 21G/38 mm, is recommended.
15. If the patient's BMI is greater than 30 kg/m<sup>2</sup>, use of a long needle, that is, 21G/50 mm, is recommended.
16. It is recommended that the psychiatrist's prescription be verified before the intramuscular injection is prepared.
17. It is recommended that no injection ever be made into an area with any cutaneous problem (skin lesion, infection, etc.).
18. When using irritating products, following the manufacturer's leaflet for its preparation and reconstitution is recommended.

19. Immediate monitoring is recommended after an intramuscular injection to check for the development of a hematoma.
  20. It is recommended that the patient's informed consent be documented in their file (potential difficulties must also be documented).
  21. It is recommended that documentation that a patient was informed of the potential adverse effects of the product be noted in his or her file.
  22. The date, time, and type of injection must be documented in the patient's file.
  23. It is also recommended to document the date of the next scheduled intramuscular injection in the file.
  24. It is recommended that the patient be informed of the date of the next intramuscular injection.
  25. It is recommended that the patient be monitored in the days following an intramuscular injections to check for hematoma, an infection, and pain.
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#### **Nurse-patient relationship**

26. It is recommended that, insofar as possible, relationship continuity (that is, limiting the fungibility of nurses) be maintained throughout the patient's care.
27. It is recommended that patients be supported throughout the procedure (before, during, and after injection) to help attenuate their negative feelings.
28. It is recommended that opportunities for touch and/or physical contact be assessed as a means of diverting situational anxiety.
29. Consideration of the effects of reassurance and the social representations associated with the administration of a long-acting intramuscular treatment is recommended.
30. Verifying the utility and value of preparing the product to be injected in the patient's presence is recommended.
31. It is recommended that the time spent preparing for the intramuscular injection procedure be used as relational support with the objective of transmitting to the patient the necessary information about the clinical procedure and providing education about the treatment.
32. After the patient has been informed about the factors involved in selecting an intramuscular injection site, it is recommended to favor his or her choice of site.
33. Giving priority to the patient's choice for the environment, injection site, and related rituals is recommended.

34. It is recommended that the professional who prepares the injection be the one to administer it.
  35. In emergencies, however, it is recommended that a professional leave the physical management of the situation to prepare and administer the intramuscular injection in less constrained conditions.
  36. It is recommended that the patient's privacy be respected.
  37. In emergencies, re-proposing an oral treatment is recommended after observing the positive impact (patient's awareness) of announcing that an injectable treatment will be used.
  38. It is recommended that non-medical techniques be used before an injection to reduce the pain at the moment of the injection.
  39. If a doctor's prescription or protocol for it exists, offering some patients an anesthetic patch or cream is recommended before the intramuscular injection to limit its pain.
  40. Depending on the patient, diverting their attention at the moment of the intramuscular injection is recommended to limit the pain.
  41. It is recommended that the patient's feelings and experience of the injection be assessed just after its administration.
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### **Pharmacology**

42. Verification that the patient is not taking any anticoagulant treatment is recommended before each new intramuscular injection.
  43. It is recommended that products be injected at room temperature.
  44. It is recommended that the decision of the speed of administration take into account the type of product (aqueous or oily solution) and the patient's muscle tone.
  45. It is recommended that the product be injected slowly to limit pain (speed less than 1 mL per 10 s).
  46. It is recommended not to massage the area after the injection.
  47. It is recommended not to massage the area after an injection of olanzapine pamoate.
  48. It is recommended not to perform a local massage after an intramuscular injection because of the pharmacokinetic modifications it may induce, especially the risk of a post-injection sedation syndrome.
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### **Hygiene**

49. Washing one's hands with a mild soap if they are visibly soiled or rubbing them together with an aqueous alcohol solution is recommended before administering an intramuscular injection.
50. It is recommended not to wear (nonsterile) gloves to prepare an intramuscular injection unless specifically recommended by the pharmaceutical manufacturer.
51. It is recommended that sterile single-use material (syringe and needle) be used to administer intramuscular injections.
52. Disinfecting the vial opening is recommended before removing the product from it to administer or reconstitute it.
53. It is recommended that the needle be changed between the syringe-filling stage and the injection stage.
54. If the injection site is visibly soiled, it is recommended that it be cleaned with mild soap, rinsed, and disinfected.
55. It is recommended that the injection site be disinfected even if it is visibly clean.
56. It is recommended that an alcohol antiseptic be used when the injection site is visibly clean.
57. In emergencies, it is recommended that the injection site be disinfected insofar as possible if it is visibly soiled.
58. When the injection site is visibly clean, it is recommended that the antiseptic be applied circularly and centrifugally.
59. After disinfecting the injection site, it is recommended to wait for it to dry before administering the injection.
60. Disinfecting one's hands with an aqueous alcohol solution is recommended before administering an intramuscular injection.
61. It is recommended that nonsterile gloves be worn to administer an intramuscular injection to limit the risk of exposure to blood.
62. It is recommended that the needle then be disposed of in a container safe for pointed/cutting/sharp objects.
63. It is recommended that a bandage be placed over the injection area in the case of blood return or reflux to the injection site.
64. Washing one's hands with a mild soap or rubbing them with an aqueous alcohol solution is recommended after administering an intramuscular injection.

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### **Injection technique**

65. It is recommended that the injection site be adapted to the patient's profile (sex and BMI).
66. It is recommended that the injections be administered, in descending order of priority, in the gluteal, the vastus lateralis, and finally the deltoid muscle.



67. It is recommended that patients with obesity (BMI  $\geq$  30 kg/m<sup>2</sup>) receive intramuscular injections in the gluteus medius (ventrogluteal site).
  68. For both men and women with a BMI < 30 kg/m<sup>2</sup>, injections into the dorsogluteal area are recommended.
  69. The deltoid site is recommended for the initiation of paliperidone palmitate treatment (loading dose).
  70. It is recommended that the injection site be adapted to the doses (or volumes) to be administered to the patient.
  71. It is recommended that the thickness of the subcutaneous tissue be assessed before an intramuscular injection to help choose the site and the needle length.
  72. While taking the patient's preference into account, alternating the deltoid and gluteal sites during the maintenance phase of treatment is recommended.
  73. It is recommended that the superolateral quadrant be chosen for intramuscular injections in dorsogluteal area to limit the risk of sciatic nerve injury.
  74. It is recommended that intramuscular injections into the deltoid be administered with the patient in a seated position, elbow to body.
  75. It is recommended that, before the injection, manual pressure be applied to the area to promote muscle relaxation and reduce pain at the moment the injection is administered.
  76. It is recommended that the Z-track technique be used for intramuscular injections to limit the risk of hematoma.  
*Definition of the Z-track technique: Before insertion of the needle, the hand not holding the syringe pulls the skin taut, moving it by several centimeters so that when the skin is released after the injection, the needle path is not aligned with the needle hole in the muscle.*
  77. It is recommended that the Z-track technique be used for intramuscular injections to limit post-injection pain.
  78. It is recommended that the Z-track technique be used for intramuscular injections to limit the leakage/dispersion of the product injected.
  79. Once the needle is in place, its aspiration is recommended before administration to avoid injection into the vessels.
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## 4 DISCUSSION

Our study, using a modified RAND-UCLA Delphi method, enabled us to elaborate 79 specific recommendations for good nursing practices in the administration of intramuscular injections in mental health (Table 3). These recommendations were classified in five major domains: legal and quality assurance aspects, nurse-patient relationship, hygiene, pharmacology, and injection technique.

The principal advantage of the Delphi method is to develop recommendations based simultaneously on the current scientific literature and to ensure their applicability in the field. This multistep method took into account the comments of the expert nurses to make the recommendations as understandable as possible for nurses on the ground (Murphy et al., 1998). The number of participants in this Delphi survey is a strength of this study. To the best of our knowledge, there are currently no clear guidelines for the sample size of participants who should be included in a Delphi study (Jorm, 2015). It has been suggested that a minimum number of experts per panel should range from 7 to 15 (Fitch et al., 2001; Okoli & Pawlowski, 2004). In our study, the larger panel of experts should certainly have increased the reliability of the final set of recommendations (Murphy et al., 1998).

The steering committee included in the final set 12 recommendations that had not been accepted in the two-round of ratings. These propositions were considered essential or mandatory in their domain either because of the high level of evidence supporting them in the literature, or because of legal or regulatory requirements, or a high level of risk for patients should the recommendation not be applied. For example, the literature has not demonstrated the effectiveness of massage against pain (Şanlıalp Zeyrek, Takmak, Kurban, & Arslan, 2019). Similarly, performance of the Z-track technique was required in view of the clear literature in favour of its use to avoid leakage of the injected product (Keen, 1990; Yilmaz, Khorshid, & Dedeoğlu, 2016).

The discordances between the expert nurses and the steering committee shows that nurses lack knowledge about these techniques. Indeed, some of the expert nurses mentioned in their comments their lack of knowledge of the Z-track injection technique, as already demonstrated (Cocoman & Murray, 2008; Franks, 2004; Legrand et al., 2019). These comments led the committee to add the definition of this technique to the recommendation for its use after the first round of Delphi. These points reinforce the need to improve both initial and continuing training in the area of intramuscular injections in mental health — itself the topic of a specific recommendation (item 1, Table 3). Moreover, manufacturers of LAIAs have various recommendations regarding injection procedure. Most of them are imprecise without literature reference such as instruction for palmitate paliperidone injection which specify to use different needle size considering patient's weight only. Our recommendation must participate to harmonize manufacturers' instructions for LAIAs.

Three other non-accepted recommendations were finally selected by the steering committee (items

26, 38, and 66, Table 3). The continuity of the nurse-patient relationship in mental health and its importance were not at all controversial among the expert panel. Only organizational and scheduling problems appear to be a limitation to the applicability of this recommendation. The steering committee specified that it must be applied “insofar as possible” (item 26). The recent literature related to item 38, concerning the use of a pre-injection technique intended to reduce pain at the moment of the injection, suggests its effectiveness (Ayinde, Hayward, & Ross, 2021). Moreover, the steering committee considered it essential to deal with patient pain. Similarly, the review of the literature about the preferred injection site suggested an order of preference descending from the gluteal muscles, to the vastus lateralis, and then the deltoid (Kamei et al., 2020; Strohfus, Palma, & Wallace, 2021). In the therapeutic arsenal of LAIAs, many manufacturers recommend injection into the deltoid. This has probably raised questions among the experts about the applicability of gluteal injection in clinical practice. One recommendation recalled that deltoid injection is specified for one currently available product (item 69, Table 3). The general recommendation was maintained as well as the current scientific data about this anatomical question (Ayinde et al., 2021).

To our knowledge, these are the first recommendations to include the issues related to the nurse-patient relationship. Thus, 16 items specifically concerning this relationship were elaborated during this process, thanks to the inclusion in the steering committee of a nurse-researcher whose pioneering work established a method to define and standardize the nurse-patient relationship in mental health (Pierrard & Lanquetin, 2015; « SocleCare—Professionnalisons nos prises en soin en psychiatrie », s. d.). These specific items invite nurses administering intramuscular injections to think about the need, to the extent possible, for one nurse to perform this procedure for a patient undergoing it regularly. Similarly, we insist on the psycho-educational aspect that the injection preparation time can take on if the nurse thinks the patient can participate in it.

For selection of the injection site, the decision to elaborate the recommendations from the perspective of the nurse-patient relationship puts the patient back as the focus of attention on this point (notions of empowerment) (Barrett et al., 2010; Crane-Ross, Lutz, & Roth, 2006; Jormfeldt, Arvidsson, Svensson, & Hansson, 2008). The nurses were thus asked, after a review of the technical recommendations for selecting the most appropriate injection site, to inform the patient of the reasons recommended and then to follow his or her choice. The technical literature is sufficiently specific for this essential question of injection site selection, even though it also shows that nurses commonly have difficulties following the existing guidelines. Several authors have noted the failure to adhere to the recommended injection techniques, specifically for site selection and use of the Z-track technique (Cocoman and Murray, 2008; Franks, 2004; Legrand et al., 2019; Wynaden et al., 2006).

Our method of recommendations development made it possible to compare scientific guidelines established for this topic with the practices of our expert nurses. We chose to vary the proposals for

the preferred injection site according to several criteria including the patient's sex, build, and the type of product. These recommendations thus remind the nurses that selection of the injection site must depend on these essential criteria (Kamei et al., 2020; Strohfus et al., 2021). Finally, patients' choices remain determinant in selecting the injection site once they have been informed of the reasons for preferring a site or a technique. Nurses also need training — both initial and continuing — to enable them to learn injection techniques according to the site selected and the Z-track method (Legrand et al., 2019).

Finally, the administration of intramuscular injections in mental health can be practiced in two quite different situations: the planned intramuscular injections of LAIAs and that of a sedative treatment for an agitated patient. We considered both situations during the recommendations development. Authors have already identified the violations of good practices, especially those related to hygiene, that occur when the procedure is performed in emergency situations (Legrand et al., 2019). Three items in these recommendations directly concern emergencies (items 35, 37, and 57, Table 3). The importance of redistributing roles in an emergency situation is noted, so that one nurse focuses on dealing with the patient while another prepares and administers the injection. Similarly, it is recommended to verify that the patient would not finally prefer to take the oral treatment just before injecting the product. One recommendation specifies the “minimal” hygiene required in this emergency situation (minimal disinfection of the injection site if it is visibly soiled).

## **5 LIMITATIONS**

There are some limitations to the current study. First, the panel of experts was exclusively composed of nurses from mental hospitals and did not include nurses involved in nursing education. Third, the results may not necessarily represent the views of all the experts chosen during the first round, given that 34.7% of experts did not respond in the second round. Fourth, the recommendations were developed in a French setting. Although they were based on international recommendations, some of them may be specific to the French context such as legal aspects as laws between countries could vary. Nevertheless, recommendations on quality and safety of care could be applied in most countries. Lastly, the final set of recommendations was not submitted to external independent review for approval, and the external validity of the recommendations must be assessed in future research.

## **6 CONCLUSION**

Our study proposed a new approach to update clinical practice recommendations for nurse-administered intramuscular injections in mental health. These recommendations and the Delphi technique used to formalize them ensure their acceptability by nurses in the field. The strength of our

study is that it places patients at the heart of the decisions concerning this procedure, which it sets more specifically in the context of the nurse-patient relationship. The concept of this relationship strengthens the important technical proposals to be implemented in daily practice. The development of these recommendations underlines the need to establish specific training programs — both initial and continuing — for this nursing procedure that has a specific character in mental health. An approach by simulation (for the technical aspects) and by role-playing (for the aspects related to the nurse-patient relationship) can be envisioned to promote their widespread dissemination (McGee, 2017). Like all new recommendations, these must be widely distributed according to a specific Action Plan so that the interval between their publication and their application in daily practice is reduced as much as possible. Moreover, their integration in the field after their distribution must be verified, by both before-and-after studies and regular assessments of professional practices by relevant indicators.

### **CRedit authorship contribution statement**

Candy Guiguet-Auclair: Data curation, Formal analysis, Methodology, Software, Visualization, Writing - original draft, Writing - review & editing.

Lise Bernard: Investigation, Validation, Visualization, Writing - review & editing.

Stéphane Boisgard: Investigation, Validation, Visualization, Writing - review & editing.

Zuzana Cardinaud: Investigation, Validation, Visualization, Writing - review & editing.

Jennifer Fernandes: Data curation, Visualization, Writing - review & editing.

Anne Debost-Legendre: Data curation, Methodology, Software, Visualization, Writing - original draft, Writing - review & editing.

Elisabeth Grégoire: Visualization, Writing - review & editing.

Jean Paul Lanquetin: Investigation, Validation, Visualization, Writing - review & editing.

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Ousmane Traore: Investigation, Validation, Visualization, Writing - review & editing.

Guillaume Legendre: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing.

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