ORIGINAL RESEARCH

# Best practice for deltoid intramuscular injections in older adults: Study in cadavers

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## ABSTRACT

Most injectable vaccines are administered via deltoid intramuscular injection (IMI). Nursing students are taught to perform deltoid IMI in their entry-to-practice education program. However, best practice evidence is lacking regarding specific techniques of deltoid IMI, and students are often taught what their instructor was taught in his/her own entry-to-practice (ETP) program. Nursing textbooks provide instructions and diagrams for how to perform deltoid IMI, but rarely cite underpinning empirical evidence. This study tested the injection techniques of bunching (squeezing) or flattening (stretching) the deltoid muscle before administering IMI using medical school donated cadavers. Flattening technique resulted in over-penetration of deltoid injections more than 85% of the time in these older adults, whereas nearly 80% of deltoid IMI are successful using bunching technique. Body mass index (BMI) and needle length are also crucial considerations when administering deltoid IMI. Nurses, and other health professionals who use deltoid IMI to administer vaccines to older adults, should determine the client's body mass index to select the appropriate needle length. Based on these results, bunching technique is recommended. Flattening technique is not recommended for older adults with a BMI < 30.

**Key Words:** Deltoid, Intramuscular injection, Vaccine administration, Needle length, Cadavers

## 1. INTRODUCTION

The PanAmerican Health Organization/World Health Organization named vaccine hesitancy as one of the top ten threats to global health in 2019.[1] To be successful, that is, to ensure optimal vaccine absorption and immune response and to minimize adverse reaction, intramuscularly administered vaccine must be injected at least 5 mm into the muscle.[2,3] Muscle tissue is highly vascular, which promotes rapid absorption of the vaccine. If vaccine is administered incorrectly into the subcutaneous fat or by over-penetrating the targeted muscle, the resulting reduction in immune response and increase in local irritation may contribute to the client's future vaccine hesitancy. Several decisions made at the point of care by the nurse administering the injection strongly influence whether or not a deltoid vaccination is successful. The age and body mass index (a measure of body fat based on height and weight) of the client, the selected needle length, the land marking technique used, and whether the nurse bunches or flattens the deltoid muscle prior to inserting the needle, all dramatically influence the success or failure of the vaccination. However, it is unlikely that the nurse was taught to consider these variables when administering deltoid intramuscular injection (IMI), and contemporary nursing fundamentals textbooks do not cite empirical evidence to support recommended practices for deltoid IMI.[4,5] Guidelines provided by government agencies are vague with respect to

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specific practice techniques for deltoid IMI.[3,6]

Nursing textbooks and entry-to-practice nursing education programs likely do not include best practice evidence for deltoid IMI because little evidence exists.[7,8] In particular, the question of whether to use bunching or flattening technique, with what needle length and with which client populations, has not been systematically addressed.[9] Nurses have reported learning one deltoid IMI technique in their entry to practice (ETP) program, with no additional training since that time. Therefore, many nurses have a ritualistic, routinized approach to administering injections and consider themselves to be experts.[5,10] As well, nurses fear striking bone when giving injections, described by Wilkoff as a "fingernails-on-the-blackboard experience" for the nurse (p. 20),[11] although the patient is unlikely to feel it.[12] "You don't want to hit bone" is a frequently-given rationale for the universal use of 25 mm needles, employing bunching technique and leaving a few millimetres of the needle out of the skin. However, the over-emphasis on avoiding the humerus deflects attention from more serious adverse outcomes of a poorly-administered deltoid vaccine, such as decreased immunogenicity, increased local reaction, and potential damage to the axillary nerve.[4] Because of the lack of evidence to support best practice for deltoid IMI, nurses are passing rote methods and unsubstantiated beliefs between colleagues and onto nursing students.[9,13]

The aim of this study is to address this gap in evidence with respect to administration of vaccine in the older adult population using bunching or flattening technique and 25 mm (1inch) or 32 mm (1.5 inch) needles. This study tested the hypothesis that three clinical decisions made by the nurse at the point of care, namely landmarking technique, bunching or flattening technique, and selection of needle length, influence whether vaccine is delivered 5 mm or more into the deltoid muscle mass. The primary objective of the study was to create strong evidence which answers the question: what is best practice for deltoid intramuscular injection in older adults?

## 2. METHOD

This quasi-experimental study used a convenience sample of donated, unenbalmed cadaver specimens to test the hypothesis. In total, 26 specimens were injected, however, 12 specimens were lost to follow up (due to procedures conducted outside this study while cadavers were used in medical training) leaving 14 specimens to be included in the analysis. All specimens were Caucasian, 10 male and 4 female, with an average age of 88 years (SD 5.5) at the time of admission into the body donation program, each specimen was given four injections: two into the right deltoid and two into the left deltoid. All injections (0.5 ml) were performed by the first author, using the same landmarking technique for each injection: the acromial process was located, and three fingers (a span of 4.5 cm) were laid horizontally, immediately below the palpated edge of the acromion, on the skin overlying the deltoid muscle. This horizontal boundary was marked on the skin. The coronal (vertical) axis of the outer upper arm was also marked on the skin. The two injections performed on each arm were located 1 cm on either side of the coronal (vertical) axis, at the horizontal line, 4.5 cm below the acromion. On the right side, using bunching technique, the deltoid muscle was squeezed between the thumb and fingers of the non-dominant hand before the needle was fully inserted to the hub, at 90 degrees to the skin. On the left side, using flattening technique, the skin overlying the deltoid muscle was stretched between the thumb and fingers of the non-dominant hand before fully inserting the needle to the hub, again at 90 degrees to the skin. Injections using flattening technique were always performed on the left deltoid; injections using bunching technique were always performed on the right deltoid. The latex injectate was colour-coded to prevent confusion in later analysis of the dissected specimens: flattening technique was always performed using blue latex and a 25 mm needle; bunching technique was always performed using green latex and a 25 mm needle. White latex was always injected with a 32 mm needle into the left and right deltoids and either flattening (left) or bunching (right) technique.

Following the injections, the entire right and left deltoid muscles, with the skin and fat layers intact, were isolated and removed by the second author, and frozen flat. The frozen deltoid specimens were then sliced superiorly to inferiorly in 6 mm (0.25 inch) slices to locate the coloured latex boluses within the muscle. Each slice was labelled and photographed. The photographs were then analyzed and visible latex boluses, muscle and fat layer thicknesses were measured using ImageJ software. Measurement and analysis of every photograph was performed collaboratively by the first author and a research assistant. The muscle layer and fat layer thicknesses were measured for every specimen whether or not the latex bolus was visible. Pre-death height and weight of the specimens was unavailable, therefore, the subcutaneous fat layer overlying the deltoid muscle was measured to determine each specimen's BMI. Cook, Williamson and Pond used ultrasonography to determine that the thickness of the subcutaneous fat layer overlying the deltoid muscle in older adults correlates to the body mass index; this correlation was used to determine the body mass index of the specimens in our study.[14] Ethical approval for the study was obtained through the University of Calgary Conjoint Health Research

Ethics Board (Study ID: REB 15-2160).

Descriptive statistics were used to analyze the morphometric data obtained from the digitized photographs (see Figure 1).

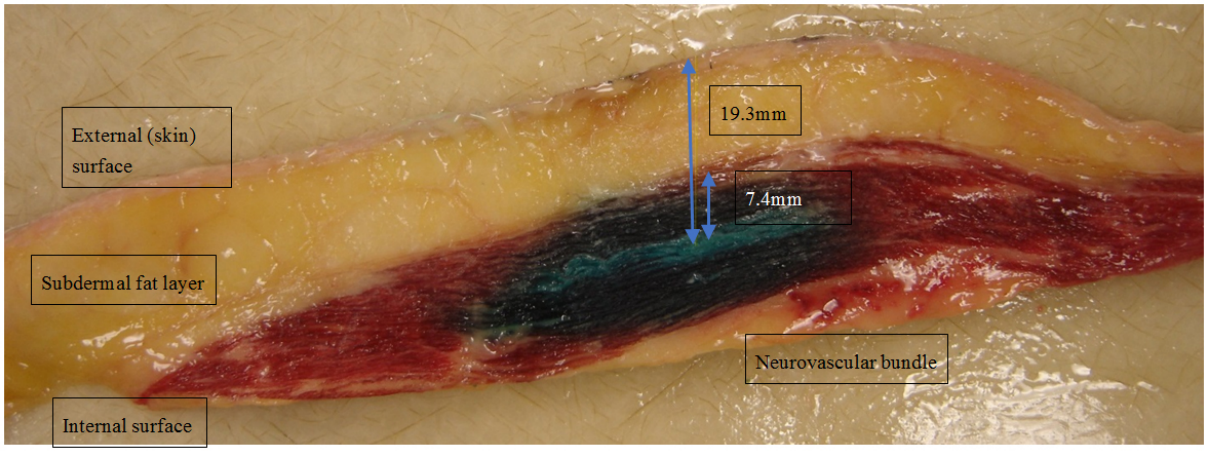


**Figure 1.** Deltoid slice showing successful injection as determined by Image measurement: centre of the latex bolus is 7.4 mm into the muscle layer and 19.3 mm from skin surface. The injection is a safe distance from the neurovascular bundle

## 3. Results

### 3.1 Bunching technique, 25 mm needle

The analysis of the photographic data obtained from the 14 specimens provided a clear answer to the study hypothesis. For the 10 male subjects, with an average estimated BMI of 25, bunching technique using a 25 mm needle resulted in eight out of 10 successful injections (see Table 1); that is, the latex bolus was found at least 5 mm into the deltoid muscle mass. The remaining two out of 10 injections using this technique overpenetrated the deltoid muscle. In the first of these overpenetrations, the specimen had significant sarcopenia, which had reduced the deltoid to a thin ribbon of muscle almost entirely taken over by fat, and BMI of 20-24.9. These factors contributed to the latex bolus being deposited at posterior aspect of the surgical neck of the humerus, in the neuromuscular bundle. The second overpenetrated specimen was not found during dissection; this specimen was also noted to have significant sarcopenia of the deltoid muscle, so much so that we were unable to differentiate the fat and muscle layers to estimate the BMI.

For all four female subjects, BMI was in the range of 20-24.9. Bunching technique using a 25 mm needle resulted in three out of four successful injections. One out of four injections overpenetrated the deltoid; the latex bolus was found at the surgical neck of the humerus. As was noted with the male subjects, this female specimen had significant sarcopenia (see Table 2).

### 3.2 Flattening technique, 25 mm needle

The use of flattening technique with a 25 mm needle resulted in a 75% failure rate in female specimens and in 70% of male specimens. Of particular concern is that when using standard landmarking (3 fingers below the acromion, 4.5 cm) and flattening technique, the latex was often injected directly into the neurovascular bundle. The overpenetrated injections were usually not found; we would speculate that these injections most likely went all the way through the deltoid, into teres minor or associated connective tissue.

**Table 1.** Results from male specimens (n = 10, average BMI = 25)

| Technique | Successful (> 5 mm into the deltoid muscle) | Overpenetrated or in the neuromuscular bundle | Injection not found on dissection (presumed overpenetrated) |
|---|---|---|---|
| Bunching, 25 mm needle | 8 | 2 | 0 |
| Bunching, 32 mm needle | 1 | 1 | 8 |
| Flattening, 25 mm needle | 0 | 6 + 3 in neurovascular bundle | 1 |
| Flattening, 32 mm needle | 1 | 2 + 1 in neurovascular bundle | 6 |

**Table 2.** Results from female specimens (n = 4, BMI 20.0-24.9)

| Technique | Successful (> 5 mm into the deltoid muscle) | Overpenetrated or in the neuromuscular bundle | Injection not found on dissection (presumed overpenetrated) |
|---|---|---|---|
| Bunching, 25 mm needle | 3 | 1 | 0 |
| Bunching, 32 mm needle | 0 | 0 | 4 |
| Flattening, 25 mm needle | 1 | 3 | 0 |
| Flattening, 32 mm needle | 0 | 0 | 4 |

### 3.3 Bunching or flattening, 32 mm needle

In our sample of older adult, non-obese specimens, a 32 mm needle overpenetrated the deltoid muscle, whether bunching or flattening technique was used. Only one out of 14 (7%) injections in this group was successful, and that specimen had a higher BMI, between 25-29.9.

### 3.4 Hitting Bone

Detailed records were kept for every injection on every specimen, therefore the incidence of striking bone is known for 26 specimens, even though 12 specimens were lost before dissection and photographs. It is significant to note that bunching technique with a 25 mm needle resulted in zero incidents of hitting bone. However, flattening technique with a 25 mm needle resulted in hitting bone in four out of 26 specimens (15%). When using a 32 mm needle, both bunching (15%) and flattening (19%) techniques resulted in hitting bone.

## 4. Discussion

The key findings of this study clearly support the hypothesis: three clinical decisions made by the nurse at the point of care, that is, landmarking technique, bunching or flattening technique, and selection of needle length, very definitely influence whether vaccine is successfully delivered 5 mm or more into the deltoid muscle mass of older adults. Nurses who consider themselves experts in performing deltoid IMI may also believe they no longer need to physically landmark because they can eyeball the client's arm to select the best injection site.[5] Our study demonstrates the hubris of this belief. Physically landmarking the intended injection site is critical for the safety of the client receiving deltoid intramuscular injection. This study demonstrates that even when a time-honoured landmarking technique (three fingers below the acromion process, 4.5 cm) is used, it is not rare to inject perilously close to, or even into, the axillary neurovascular bundle. Using flattening technique and a 25 mm needle, almost 30% of injections imperilled the axillary neurovascular bundle. Obviously, with cadaver specimens, we were unable to assess whether actual clinical harm had occurred. However, upper arm and shoulder injury related to vaccine administration is an emerging, and likely under-reported, phenomenon.[12, 15–17] The standard deltoid landmark needs to be updated: three fingers below the acromion should be considered the upper (superior) boundary for safe deltoid injections, and an additional lower boundary, at the axillary line, should be added for optimal client safety. The safe injection zone is between these upper and lower boundaries, along the coronal (vertical) axis of the outer aspect of the client's arm. After determining which arm will be receiving the injection, asking the client to press that hand into their hip adducts the shoulder and improves visualization of the deltoid muscle prior to injection.[16] We add levity by first demonstrating and describing shoulder adduction as a supermodel pose, and then asking the client to "show me your best supermodel pose". The client and the nurse should both be seated at the same level, to ensure the needle is injected at 90 degrees to the skin.[12]

The question of whether bunching or flattening technique is more successful in delivering vaccine at least 5 mm into the deltoid muscle of older adults is also answered by our study. Overall, bunching technique with a 25 mm needle is nearly 80% successful in delivering the vaccine without overpenetrating the deltoid, whereas flattening technique with a 25 mm needle is the opposite: more than 85% unsuccessful. Nurses have stated that they use bunching or flattening because they have always done so.[5] Based on our data, nurses should not use flattening technique for deltoid IMI with older adults. After determining the upper (three fingers below the acromion) and lower (axillary line) limits of the safe injection zone, the nurse should place his/her non-dominant thumb and fingers on the sides of the arm to lift, or bunch, the deltoid muscle before inserting the needle to the hub.

The appropriate needle length for deltoid IMI with older adults is also clear in our data. As noted above, bunching technique using a 25 mm needle is the most likely to be successful in delivering vaccine at the appropriate depth in the deltoid muscle. However, using at 32 mm needle with either bunching or flattening technique was unsuccessful in all but one specimen. The vast majority of injections with a 32 mm needle entirely overpenetrated the deltoid muscle, and were either not found in the dissected deltoid or were found in tissues deep to the deltoid muscle. Body mass index

(BMI) should be used to determine the correct needle length for intramuscular injections. This knowledge is not new, although it is rarely used in practice.[3,14] The challenges of knowledge translation in nursing are widely known, and beyond the scope of this paper. However, it bears repeating that BMI is a crucial consideration for safe intramuscular injections. Skin fold calipers may be a more practical point-of-care test than BMI for quickly determining a client's body fat in a busy vaccination clinic, however, this requires further study. In our study, using a 25 mm needle and bunching technique, specimens with BMIs between 25-29.9 had no incidence of overpenetration. However, specimens with a BMI between 20-24.9 had a 25% incidence of overpenetration with a 25 mm needle and bunching technique. Older adults with low BMI may require a 16 mm (5/8") needle to prevent overpenetration, although this requires further study. As previously noted, flattening technique was strongly correlated with overpenetration, in particular, when lower BMI (20-24.9) was combined with flattening technique, nearly all injections overpenetrated.

Sarcopenia is common in older adults, and is an important contributor to frailty. The measurement and management of sarcopenia is an emerging science which holds considerable implications for safe administration of deltoid IMI to older adults. In our study, the average age of the specimens at the time of death was 88 years, and three of 14 (21%) specimens were noted to have significant deltoid sarcopenia upon detailed inspection of the dissected deltoid specimens. This prevalence is similar to what has been reported in the literature.[18,19] Providing safe deltoid IMI with optimal immunogenicity in the presence of significant sarcopenia, which has reduced the deltoid to a thin ribbon of muscle almost entirely taken over by fat, is an emerging clinical dilemma.

This study using cadaver specimens has both strengths and limitations. Having the registered nurse co-investigator administer all injections, consistently using the same landmarking technique to select the injection sites, minimized procedural variability. Similarly, having the second author perform all dissections minimized procedural variability. Directly examining latex injectate in dissected deltoid muscle, and determining the correlation to bunching and flattening technique and needle length, has not been previously attempted. Previous studies employing ultrasound to observe and measure intramuscular injections[14,20] are limited by transducer pressure applied during ultrasound, which potentially compresses the tissues, altering the measured depth of the injection and of fat and muscle layers.[9] By physically visualizing and measuring the placement of the injectate in the deltoid, we were able to determine the combination of factors which resulted in successful deltoid IMI or in over-penetration. The unanticipated prevalence of sarcopenia, and its implications for deltoid IMI, are important considerations for future study. This study relied on the availability of donated cadaver specimens, which had limitations. The average age of the specimens at time of death was 88 years, which limits the generalizability of the results to younger populations. Male specimens were over-represented in body donations. Obese individuals were excluded from the study due to the acceptance policies of the body donation program used, therefore we cannot comment on the implications of our results in obese populations. The body donation program strictly adheres to the ethical imperative to make optimal use of donated cadavers, which meant that we were able to do the initial injections when the cadaver was accepted into the program but it was usually many months (mean 20 months, SD 7.8 months) before we were able to remove the deltoids, just prior to the cremation of the cadaver. As well, unfortunate circumstances resulted in the loss of 12 specimens before the injected deltoid muscles were retrieved. A larger sample size would have strengthened these findings.

## 5. Conclusion

The primary objective of the study was to create strong evidence which answers the question: what is best practice for deltoid intramuscular injection in older adults? We believe we have an answer. First, nurses must obtain the older adult's BMI to select the appropriate needle length.[3,14] Second, nurses must never eyeball the location for a deltoid intramuscular injection. The nurse must measure his/her own fingers on the non-dominant hand to determine the number of fingers required to span at least 5cm; this measurement is critical to accurate landmarking. Next, nurses need to be able to accurately locate the acromion process to determine the upper and lower boundaries of the safe injection zone, and aim for the centre of the safe zone, midline on the deltoid surface along the coronal (vertical) axis. Bunching technique with a 25 mm needle was successful nearly 80% of the time in this population; flattening technique should not be used. In a non-obese population, 32 mm needles will overpenetrate the deltoid muscle.

The use of this evidence will provide the nurse with the knowledge, skills and abilities to avoid arm and shoulder injuries related to deltoid vaccination,[12,16] and to avoid improper vaccine administration technique which may contribute to vaccine hesitancy. We owe it to our clients and to the nursing profession to be part of the solution.

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## CONFLICTS OF INTEREST DISCLOSURE

The authors declare that there is no conflict of interest.

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