



Upper limb nerve injuries caused by intramuscular injection or routine venipuncture

Department of Anesthesiology and Pain Medicine, Jeju National University School of Medicine, Jeju, Korea

Hyun Jung Kim, Sun Kyung Park, and Sang Hyun Park

The reported cases of upper limb nerve injury followed by needle procedure such as intramuscular injection or routine venipuncture are rare. However, it should not be overlooked, because neurological injury may cause not only minor transient pain but also severe sensory disturbance, hand deformity and motor dysfunction with poor recovery. Recognizing competent level of anatomy and adept skill of needle placement are crucial in order to prevent this complication. If a patient notices any experience of abnormal pain or paresthesia during the needle procedures, an administrator should be alert to the possibility of nerve injury and should withdraw the needle immediately. Careful monitoring of the injection site for hours is required for early detection of nerve injury. (*Anesth Pain Med* 2017; 12: 103-110)

Key Words: Intramuscular injections, Median neuropathy, Peripheral catheterization, Peripheral nerve injuries, Radial neuropathy, Ulnar neuropathies.

INTRODUCTION

Intramuscular injection into the upper limb is a popular clinical technique for vaccination or other drug administration. Venipuncture into the upper limb is also a routine procedure for blood sampling, intravenous injection and cannulation. However, these procedures are not always safe and may cause nerve injuries in various degrees.

The reported overall incidence of upper limb nerve injuries following intramuscular injection or routine venipuncture is

rare. A study [1] estimated annual incidence of nerve injury was 3.38 per 1,000,000 intramuscular injections (8% of which involved upper limb) in children under 15 years of age. Other studies on the blood donors showed that the incidence of needle-related nerve injuries ranged from 1/1,400 to 1/6,300 donations [2,3]. However, considering the high frequency of these procedures, it may be underreported due to the lack of recognition and diagnosis.

Several mechanisms are associated with injection-related nerve injury; direct needle trauma, toxic effects of injected agents on nerve fibers and surrounding tissues, nerve compression due to hematoma or edema formation, and so on. Among them, direct needle trauma is the most frequent factor. Therefore, sufficient knowledge of anatomy, understanding of procedure, and adept skills in needle placement are essential to avoid these complications [4,5].

The present article reviews upper limb nerve injuries caused by intramuscular injection or routine venipuncture including anatomic basis, methods for prevention and appropriate injection techniques.

MATERIALS AND METHODS

The electronic databases MEDLINE, PubMed, Google Scholar were searched for relevant articles from 1970 to 2016. Search terms were comprised of the specific upper limb nerve, injury, intramuscular injection and venipuncture.

AXILLARY NERVE INJURY

Anatomy

Axillary nerve is a terminal branch of the posterior cord of the brachial plexus formed by C5 and C6 spinal roots. It

Received: December 29, 2016.

Accepted: February 17, 2017.

Corresponding author: Sang Hyun Park, M.D., Ph.D., Department of Anesthesiology and Pain Medicine, Jeju National University School of Medicine, Aran 13-gil 15, Jeju 63241, Korea. Tel: 82-64-717-2029, Fax: 82-64-717-2042, E-mail: painman70@gmail.com

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

descends backward with the posterior humeral circumflex artery and exits axilla posteriorly through a quadrilateral space. Then it forms anterior and posterior branches beneath the deltoid muscle. It innervates the deltoid and teres minor muscles, and gives cutaneous supply over the deltoid region and superior posterior arm [6,7].

Reports

The axillary nerve could be damaged by intramuscular injection into the deltoid. Tak et al. [8] investigated 310 patients with nerve injuries after intramuscular injections. Among them, 3 (1%) patients had axillary nerve injury; it is the third most common lesion following sciatic and radial nerve injuries. Davidson et al. [6] reported a case of axillary nerve injury after a deltoid intramuscular injection of antiemetics. Choi et al. [9] also reported a case of axillary nerve injury after deltoid intramuscular injection of atropine and hydroxyzine as a preoperative medication.

Presentation

If the injury is caused directly by the needle tip, the patient typically complains of immediate, sharp, and electric-like pain over the shoulder at the time of injection. However, if the pure motor branch of the axillary nerve is injured, the patient could not suffer pain and could only have deltoid muscle wasting and shoulder weakness, especially abduction [6,9].

Deltoid intramuscular injection technique

The suitable intramuscular injection site in upper limb is the deltoid muscle. The deltoid is a triangular-shaped muscle that originates from the lateral one third of the clavicle, the

acromion, and the spine of the scapula. It converges downward into the deltoid tuberosity near the middle of the humerus. As the axillary nerve courses beneath the deltoid muscle and supplies the muscle, it is clearly vulnerable to needle injury. Subdeltoid bursa and circumflex humeral arteries are other at-risk structures from a deltoid injection (Fig. 1) [10,11].

Although deltoid intramuscular injection is considered a routine clinical procedure, occasionally it is performed incorrectly. One of the most extensive investigation on this topic was scrutinized by McGarvey and Hooper [11]. They reviewed deltoid intramuscular injection technique by 50 general practitioners and 50 nurses, and found that there was a lack of awareness of anatomy and proper injection techniques.

The recommended injection site is the midpoint of the deltoid muscle (the densest part of the muscle) or approximately 3–5 cm below the lower edge of the acromion on midway between acromion and deltoid tuberosity (Fig. 2). Excessive proximal site could lead to bursa injection, while excessive distal site could lead to nerve damage or injection into vessels [11,12]. However, cadaver studies indicated that the distance from the tip of the acromion to the axillary nerve had as wide a range of 4–8 cm, with an average distance of 5–6 cm. So, a deltoid injection near 5 cm below the acromion may injure the axillary nerve. If the patient's arm is abducted, the axillary nerve moves closer to the acromion and the risk of the nerve injury increases. Furthermore, the subdeltoid bursa may extend 5 cm below the acromion. Therefore, unfortunately, no site offers an absolute protection against at-risk structures [7,11,13].

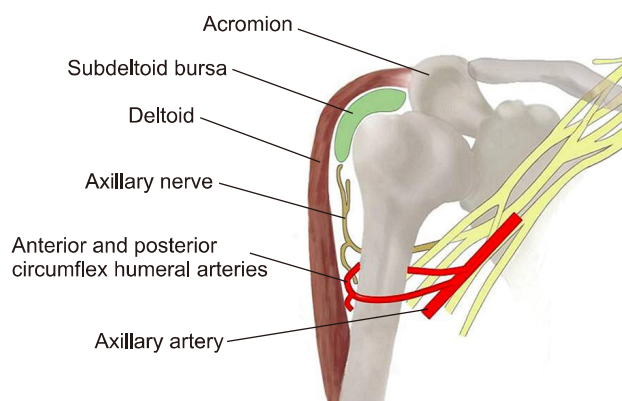


Fig. 1. The deltoid muscle and surrounding structures. It is important to raise the awareness of at-risk structures from a deltoid intramuscular injection (axillary nerve, subdeltoid bursa and circumflex humeral arteries).

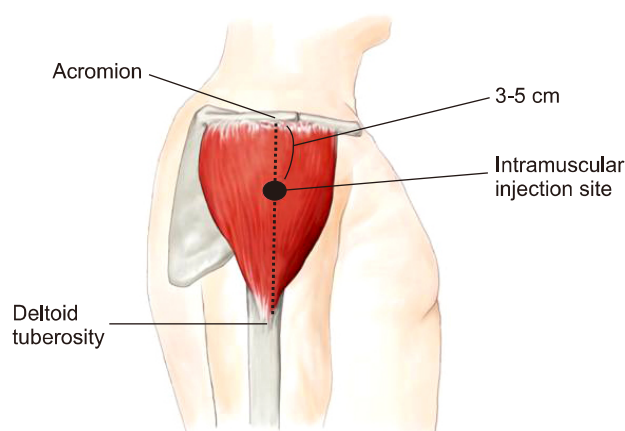


Fig. 2. The site for deltoid intramuscular injection. The recommended intramuscular injection site is approximately 3–5 cm below the lower edge of the acromion on midway between acromion and deltoid tuberosity.

The deltoid intramuscular injection is not recommended in young children due to the inadequate muscle mass. Even in adults, it is not recommended in patients who are thin with debilitating diseases as the same reason. Additionally, the number and volume of injections should be limited due to its small muscle mass. The suggested maximum injection volume at a deltoid site is 1–2 ml [10,12].

The selection of needle length is also crucial. The needle should be long enough to reach the muscle mass and to prevent subcutaneous injection, but not so long to involve underlying nerves, blood vessels, or bones. Appropriate needle length in adults depends on patient's sex and weight (Table 1) [14,15].

It is important to recognize the possibility of nerve injury following an intramuscular injection. If a patient experiences any abnormal pain or paresthesia during the injection, the needle should be immediately withdrawn. Careful monitoring and observation of the injection site is also important for an early detection of nerve damage. Two to four hourly post-injection observation of the injection site is recommended [12].

RADIAL NERVE INJURY

Anatomy

The radial nerve is the major outflow from the posterior cord of the brachial plexus formed by C5–T1 spinal roots. It descends down the posterior aspect of the humerus along the radial groove and wraps around the humerus in a lateral direction. Then it moves anteriorly over the lateral epicondyle of the humerus and passes the antecubital fossa (Fig. 3) [16].

It provides motor innervation to the posterior compartment of the arm and forearm responsible for extension of the elbow, wrist and fingers. It also provides sensory innervation to the posterior arm, posterior forearm, and lateral two-thirds of the

dorsum in the hand and fingers [5,16].

Reports

The radial nerve is the most commonly injured nerve in the upper extremity after intramuscular injection. Tak et al. [8] investigated 310 patients with nerve injuries after intramuscular injections. Among them, 29 (9.4%) patients had a radial nerve injury. Pandian et al. [17] identified 29 (43.9%) patients having suffered a radial nerve injury among the 66 intramuscular injection related nerve injury patients. Above two reports, radial nerve injury is the second most common lesion after sciatic nerve injury. There are also several case reports of radial nerve palsy following intramuscular injection into the arm [18].

Venipuncture near or at the elbow level can also involve the radial nerve. Edwards and Fleming [19] described a patient with a complete radial nerve palsy after the cephalic vein cannulation in the lateral aspect of his arm near the elbow. This lesion probably occurred as a result of a direct needle puncture of the radial nerve through the extensor carpi radialis longus muscle.

Presentation

Pain is the most frequent symptom of a nerve injury. It is usually described as a severe shooting or burning sensation at the injection site with radiation to the dorsum of the forearm

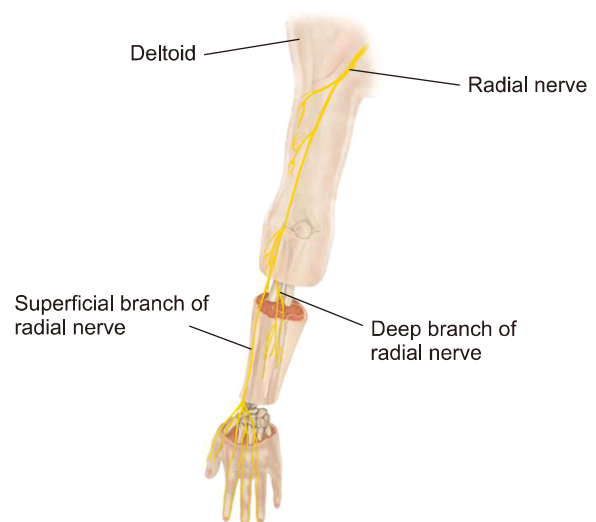


Table 1. Recommendation of Needle Length for Deltoid Intramuscular Injection in Adults

| Weight | Needle length | |
|-----------|------------------------------------|------------------------------------|
| | Male | Female |
| < 60 kg | 5/8 inch (16 mm) 1 inch (25 mm) | 5/8 inch (16 mm) 1 inch (25 mm) |
| 60–90 kg | 1 inch (25 mm) | 1 inch (25 mm) |
| 90–118 kg | 1 inch (25 mm) | 1.5 inch (38 mm) |
| > 118 kg | 1.5 inch (38 mm) | 1.5 inch (38 mm) |

Fig. 3. The course of radial nerve. The intramuscular injection should be given into the deltoid muscle due to the superficiality of the radial nerve in the mid-third of the arm. The superficial branch of the radial nerve enters subcutaneous plan in the posterior aspect of the distal forearm closely to the cephalic vein, so the nerve is vulnerable to injury during venipuncture around the wrist.

and hand. Patients could also present numbness, paresthesia, hypoesthesia and other sensory disturbance. Simple sensory deficits without pain may be functionally less significant because they involve the anatomical snuffbox and the radial dorsum of the hand. Motor function injury induces weakness when extending the forearm, wrist, and fingers. This condition is called “wrist drop” or “finger drop” [16,18,19].

Prevention

The radial nerve locates very superficially in the middle third of the lateral aspect of the arm. Therefore, an intramuscular injection into this site could result in damaging the nerve. The intramuscular injection site in upper limb should be selected midway between the acromion and deltoid tuberosity of humerus, i.e. the deltoid muscle [16,18].

For venipuncture near the elbow level, selection of an injection site and a proper needle procedure are important. Detailed technique is described in “*Venipuncture technique in the antecubital fossa.*”

ULNAR NERVE INJURY

Anatomy

Ulnar nerve is a continuation of the medial cord of brachial plexus formed by C8 and T1 spinal roots. The nerve maintains a position medial to the axillary and brachial arteries in the upper arm and descends on the posteromedial aspect of the humerus. It innervates most of the intrinsic muscles of the hand, and muscles of the flexor carpi ulnaris and medial half flexor digitorum profundus in the arm and forearm. It also provides sensory innervation to medial surface of dorsum and palm of the hand [5,20].

Reports

Injection-related ulnar nerve injury seems to be relatively rare. Kim et al. [20] analyzed 645 patients with ulnar nerve injury for 30 years and discovered only 2 injuries (0.3%) were caused by injection. Geiringer and Leonard [21] reported 2 cases of ulnar nerve injury at the arm level who received intramuscular injection for immunization. The patients were asked to fixate their hands on the hips and rotate their arms. Then the injection was administered to patients’ sidearm while the nurse was standing at the patients’ side. Combining this position of arm rotation with a sidearm delivery facilitated administration on the medial-lying neurovascular bundle instead

of the target deltoid muscle. Salanga and Hahn [22] also reported an arm level ulnar nerve injury caused by a jet injection for vaccination. Relatively small size of the patient and small muscle mass were the deduced causes of the nerve injury. Excessive arm rotation by the operator during the injection exposed the nerve making it more vulnerable to an injury by the liquid jet.

Presentation

As other nerve injuries, pain is the most frequent symptom that patients suffer. The symptoms could include numbness, paresthesia, hypoesthesia and other sensory disturbance in the innervated area. Motor function injury could result in weakness of finger abduction and adduction, fourth and fifth finger flexion, wrist adduction and wrist flexion. Atrophy of hypothenar eminence and interosseous muscles is also a frequently reported symptom [21,22].

Prevention

Intramuscular injection frequently targets the deltoid muscle as the injection site. Although the ulnar nerve in the upper arm is located in the medial aspect and far from the deltoid, inappropriate position such as excessive arm rotation could facilitate missing the muscle completely and damaging the ulnar nerve. Superficial location of the ulnar nerve under the skin makes it vulnerable to such injury. Patients that lack subcutaneous tissue and muscle could face more vulnerability to this traumatic injury. Injection complications can be prevented by administering the injection by properly trained staff that holds sufficient anatomical knowledge [21,22].

MEDIAN NERVE INJURY

Anatomy

The median nerve arises from the lateral and medial cords of brachial plexus formed by C5-T1 spinal roots. It then runs down with the brachial artery on the medial side of the arm and enters the anterior compartment of the forearm via the antecubital fossa. It provides motor innervation to anterior compartment of the forearm responsible for flexion of the wrist and fingers and sensory innervation to the lateral two-thirds of the palm in the hand and fingers [5].

At 5–8 cm distal to the medial epicondyle of the humerus, the anterior interosseous nerve arises on the radial aspect of the median nerve. It is a pure motor nerve to the flexor

pollicis longus, flexor digitorum profundus to the index and sometimes middle fingers, and to the pronator quadratus [23].

Reports

Kohn et al. [24] reported a patient with permanent median nerve injury. The patient intermittently received intravenous heparin. A large hematoma was developed after an antecubital venipuncture and the median nerve was found to be compressed by a blood clot. The anterior interosseous nerve injuries were also discovered after a routine blood sampling or peripherally inserted central catheter line insertion into the antecubital fossa [23,25,26].

Presentation

Proximal median nerve lesion induces functional loss of forearm pronation and flexion of the wrist and fingers with median nerve distribution sensory disturbance. In case of the isolated anterior interosseous nerve injury, although no sensory loss occurs, pain may be present in the forearm along the course of the nerve. Most patients have weakness to flex the distal phalanges of the index finger and thumb. Patients typically are unable to make an "OK" sign or to pinch a sheet of paper using their thumb and the index fingers [23,25,26].

Prevention

For venipuncture near the elbow level, cautious selection of an injection site and proper needle procedures are important. Detailed technique is described in "*Venipuncture technique in the antecubital fossa.*"

CUTANEOUS NERVE INJURY

Superficial branch of the radial nerve injury

1. Anatomy

Superficial branch of the radial nerve divides from the main radial nerve distal from the elbow. It runs down on the radial side of the forearm beneath the brachioradialis muscle. At the junction of the middle and distal third of the forearm, it emerges and enters a subcutaneous plane in the posterior aspect of the forearm (Fig. 3). In this subcutaneous plane, the nerve lies close to the cephalic vein. It is a sensory nerve which gives nerve supply to dorsal aspect of the thumb, index finger, and radial side of the middle finger except the nail

beds [27-29].

2. Reports

There are several case reports of the superficial branch of the radial nerve injury after a routine venous cannulation or a blood sampling in dorsolateral side near the wrist [28-33]. Horowitz [34] examined 11 patients with nerve injuries following routine venipuncture. Among them, 2 (18%) patients affected superficial branch of the radial nerve.

3. Presentation

Direct superficial branch of the radial nerve injury by needle or catheter induces immediate pain and paresthesia in the dorsolateral surface of the distal forearm radiating to the dorsum of the hand. Because this nerve is a pure sensory nerve, its injury does not affect muscle atrophy or weakness [28,31].

This nerve injury is often considered insignificantly, because its injury does not hamper daily activities and symptoms are typically transient. However, patients may suffer excruciating pain and paresthesia for a prolonged period of time that will discourage them from working. Many previous reports state conservative treatment was not successful and surgical exploration was needed to relieve the symptoms [29,31,33].

4. Prevention

Cephalic vein in the dorsolateral forearm is a common location for venipuncture due to its large size and easy accessibility. Cephalic vein's proximal location to the wrist lessens the chance of kinking the catheter. However, because the superficial branch of the radial nerve enters subcutaneous plane and locates close to the cephalic vein in this area, the nerve is vulnerable to needle-induced damages. Additionally, the position of forearm pronation and wrist flexion during the venipuncture restricts the movement of the nerve and makes it more vulnerable [27,28].

It is difficult to choose particular venipuncture site in the dorsolateral forearm to avoid superficial branch of the radial nerve injury due to the variable courses of the nerve. Vialle et al. [27] investigated 33 specimens to confirm the risk of a nerve lesion. They could not identify a safe zone, because of the randomly located nerve and vein crossing zones, where the risk of the nerve injury is maximal. They suggested that the cephalic vein should be punctured above the emergence of the superficial branch of the radial nerve, at least 12 cm above

the level of radial styloid process. Other studies also recommended that cephalic venipuncture at wrist should be avoided in the distal second quarter of the forearm and should be located 55 mm more proximal area from radial styloid process [35,36].

Medial/lateral antebrachial cutaneous nerve injury

1. Anatomy

The medial antebrachial cutaneous nerve arises from the medial cord of the brachial plexus. It runs down the ulnar side of the arm medial to the brachial artery and pierces the deep fascia with the basilic vein above the medial epicondyle of the humerus (Fig. 4). It is a pure sensory nerve which provides cutaneous sensation to the medial forearm [37].

The lateral antebrachial cutaneous nerve originates from the musculocutaneous nerve. It passes behind the cephalic vein and pierces the deep fascia lateral to the biceps tendon (Fig. 4). It is a pure sensory nerve which provides cutaneous sensation to the lateral forearm [38,39].

2. Reports

The reports about the incidence of venipuncture-related medial/lateral antebrachial cutaneous nerve injuries are limited. Although particular nerves were not specified, two studies on the blood donors showed that the incidence of needle-related nerve injury ranges from 1/1,400 to 1/6,300 donations [2,3].

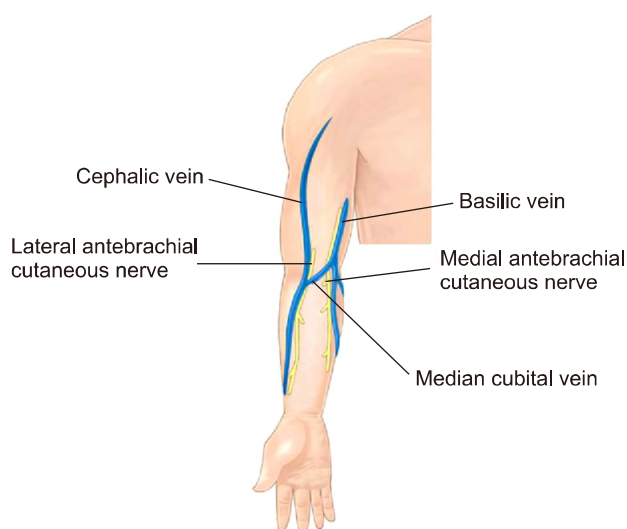


Fig. 4. Veins and cutaneous nerves in the antecubital fossa. Median cubital vein near the cephalic vein is the first choice for a routine venipuncture to cause nerve damage least likely.

There are also several case reports of the medial or lateral antebrachial cutaneous nerve injury after routine venipuncture in the antecubital fossa [37-40]. Horowitz [34] examined 11 patients with nerve injury after routine venipuncture. Among them, 5 (45%) patients affected the medial antebrachial cutaneous nerve and 2 (18%) patients affected the lateral antebrachial cutaneous nerve.

3. Presentation

Direct nerve injury results in immediate shooting and electric-type pain on the medial or lateral aspect of the forearm, according to the affected nerve [37-39]. But, in case of a nerve injury due to subcutaneous extravasation of drugs or hematoma formation, patient's symptoms may begin lately. A study of nerve injuries on the blood donors, the symptom of pain occurred at venipuncture (24%), during the bleeding (24%), or after the donation (17%). The remaining (34%) experienced only paresthesia during or after the donation [2]. Because they are pure sensory nerve, physical examination shows normal inspection and muscles power [37,38].

4. Venipuncture technique in the antecubital fossa

Venipuncture in the antecubital fossa is a routine procedure at most medical institution. However, the anatomical relationships of superficial veins and cutaneous nerves in this area are in close proximity. The nerves and the veins are located around the same depth and often these two are not separated by fascia. Moreover, they sometimes overlay and intertwine with each other. This makes the nerves vulnerable to traumatic injury during the venipuncture [41].

Median cubital vein is the first choice for a routine venipuncture in the antecubital fossa. Yamada et al. [42] performed cadaveric dissections to determine anatomical relationships between cutaneous nerves and veins in the antecubital fossa. Although no single area suitable for all individuals was identified due to a wide variation of the distribution of cutaneous veins and nerves, they suggested a puncture of the median cubital vein near the cephalic vein is the least likely site to be damaged.

If the median cubital vein is unavailable or unsuitable, then the cephalic and basilic vein could be attempted carefully. However, the area just lateral to the biceps tendon at the elbow should be avoided to prevent the lateral antebrachial cutaneous nerve injury [40,43]. Puncturing basilic vein also runs the risk of damaging nerve or artery and is usually more painful [44].

During the venipuncture, needle should be inserted as shallow as possible at an angle of 5–15° from the skin with caution not to advance deeply. Multiple attempts, needle probing, or puncture into the opposite vein wall should be avoided. It is also recommended to use the patient's non-dominant arm firstly, if feasible [28,30].

Nonetheless, even after a non-traumatic and satisfactory venipuncture, the risk of nerve damage still exists due to the high anatomic variation between nerves and veins in upper limbs. Therefore, the patient should be encouraged to immediately inform any experience of abnormal pain or paresthesia during venipuncture. If there is any notice, the needle should be immediately withdrawn. Monitoring of the injection site is also important for an early detection of nerve damage [30,39].

MANAGEMENT

The clinical courses of needle-related nerve injury range from transient minor pain to severe sensory disturbance and motor loss with poor recovery. A study of blood donation-related nerve injury reported that almost patients achieved a full recovery and some patients had only a mild/localized numbness [3]. However, another study of blood donation-related nerve injury reported that 21.6% of patients suffered pain/sensory change more than 1 year and 10% of patients had more than 5% reduction in the working capacity [2]. A study of children with traumatic injection neuropathy also reported that 29.4% of patients had residual paralysis at 60 days after nerve injury [1].

The management is generally similar to that of other nerve lesions in continuity. After nerve injury, axonal regeneration is proceeding and initial symptoms are gradually improved over time. Therefore, patients with minor sensory/motor disturbance could be observed for several months with conservative treatment. It includes medications for acute neuropathic pain such as opioids, non-opioid analgesics, adjuvant analgesics and systemic glucocorticoid. Physiotherapy and assistive devices are also needed to prevent atrophy of affected limb and to encourage proper posture [4,5,45].

However, early surgical exploration without waiting axonal regeneration is recommended in patients with intractable pain or severe neuromotor functional loss. Surgery is also recommended in patients without sign of recovery within 3–6 months after nerve injury. Surgical technique of neurolysis is indicated when nerve action potential is present across a nerve

lesion in continuity. If not, nerve resection with repair or graft is needed [16].

CONCLUSIONS

Upper limb nerve injuries caused by intramuscular injection or routine venipuncture is rare, but it could lead to severe impairment of sensory and motor function with poor recovery. Sufficient anatomical knowledge and adept skills in needle placement can hugely contribute to the prevention of intramuscular nerve injuries. It is important to recognize the possibility of nerve injuries during these procedures and to monitor the injection site for an early detection of trauma.

ACKNOWLEDGEMENTS

This work was supported by a research grant from Jeju National University Hospital in 2014.

REFERENCES

1. Mansoor F, Hamid S, Mir T, Abdul Hafiz R, Mounts A. Incidence of traumatic injection neuropathy among children in Pakistan. *East Mediterr Health J* 2005; 11: 798-804.
2. Sorensen BS, Johnsen SP, Jorgensen J. Complications related to blood donation: a population-based study. *Vox Sang* 2008; 94: 132-7.
3. Newman BH, Waxman DA. Blood donation-related neurologic needle injury: evaluation of 2 years' worth of data from a large blood center. *Transfusion* 1996; 36: 213-5.
4. Jung Kim H, Hyun Park S. Sciatic nerve injection injury. *J Int Med Res* 2014; 42: 887-97.
5. Kim HJ, Park SH, Shin HY, Choi YS. Brachial plexus injury as a complication after nerve block or vessel puncture. *Korean J Pain* 2014; 27: 210-8.
6. Davidson LT, Carter GT, Kilmer DD, Han JJ. Iatrogenic axillary neuropathy after intramuscular injection of the deltoid muscle. *Am J Phys Med Rehabil* 2007; 86: 507-11.
7. Loukas M, Grabska J, Tubbs RS, Apaydin N, Jordan R. Mapping the axillary nerve within the deltoid muscle. *Surg Radiol Anat* 2009; 31: 43-7.
8. Tak SR, Dar GN, Halwai MA, Mir MR. Post-injection nerve injuries in Kashmir: a menace overlooked. *J Res Med Sci* 2008; 13: 244-7.
9. Choi HR, Kondo S, Mishima S, Shimizu T, Hasegawa Y, Ida K, et al. Axillary nerve injury caused by intradeltoid muscular injection: a case report. *J Shoulder Elbow Surg* 2001; 10: 493-5.
10. Nicoll LH1, Hesby A. Intramuscular injection: an integrative research review and guideline for evidence-based practice. *Appl Nurs Res* 2002; 15: 149-62.

11. McGarvey MA, Hooper AC. The deltoid intramuscular injection site in the adult. Current practice among general practitioners and practice nurses. *Ir Med J* 2005; 98: 105-7.
12. Rodger MA, King L. Drawing up and administering intramuscular injections: a review of the literature. *J Adv Nurs* 2000; 31: 574-82.
13. Apaydin N, Tubbs RS, Loukas M, Duparc F. Review of the surgical anatomy of the axillary nerve and the anatomic basis of its iatrogenic and traumatic injury. *Surg Radiol Anat* 2010; 32: 193-201.
14. National Center for Immunization and Respiratory Diseases. General recommendations on immunization --- recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep* 2011; 60: 1-64.
15. Poland GA, Borrud A, Jacobson RM, McDermott K, Wollan PC, Brakke D, et al. Determination of deltoid fat pad thickness. Implications for needle length in adult immunization. *JAMA* 1997; 277: 1709-11.
16. Esquenazi Y, Park SH, Kline DG, Kim DH. Surgical management and outcome of iatrogenic radial nerve injection injuries. *Clin Neurol Neurosurg* 2016; 142: 98-103.
17. Pandian JD, Bose S, Daniel V, Singh Y, Abraham AP. Nerve injuries following intramuscular injections: a clinical and neurophysiological study from Northwest India. *J Peripher Nerv Syst* 2006; 11: 165-71.
18. Ling CM, Loong SC. Injection injury of the radial nerve. *Injury* 1976; 8: 60-2.
19. Edwards WC, Fleming LL. Radial nerve palsy at the elbow following venipuncture-case report. *J Hand Surg Am* 1981; 6: 468-9.
20. Kim DH, Han K, Tiel RL, Murovic JA, Kline DG. Surgical outcomes of 654 ulnar nerve lesions. *J Neurosurg* 2003; 98: 993-1004.
21. Geiringer SR, Leonard JA Jr. Injection-related ulnar neuropathy. *Arch Phys Med Rehabil* 1989; 70: 705-6.
22. Salanga VD, Hahn JF. Traumatic ulnar neuropathy from jet injection: case report. *J Trauma* 1979; 19: 283-4.
23. Puhaindran ME, Wong HP. A case of anterior interosseous nerve syndrome after peripherally inserted central catheter (PICC) line insertion. *Singapore Med J* 2003; 44: 653-5.
24. Kohn D, Bush A, Kessler I. Risk of venepuncture. *Br Med J* 1976; 2: 1133.
25. Zubairy AI. How safe is blood sampling? Anterior interosseous nerve injury by venepuncture. *Postgrad Med J* 2002; 78: 625.
26. Ulrich D, Piatkowski A, Pallua N. Anterior interosseous nerve syndrome: retrospective analysis of 14 patients. *Arch Orthop Trauma Surg* 2011; 131: 1561-5.
27. Vialle R, Pietin-Vialle C, Cronier P, Brillu C, Villapadierna F, Mercier P. Anatomic relations between the cephalic vein and the sensory branches of the radial nerve: How can nerve lesions during vein puncture be prevented? *Anesth Analg* 2001; 93: 1058-61.
28. Sheu JJ, Yuan RY. Superficial radial neuropathy following venepuncture. *Int J Clin Pract* 2001; 55: 422-3.
29. Thrush DN, Belsole R. Radial nerve injury after routine peripheral vein cannulation. *J Clin Anesth* 1995; 7: 160-2.
30. So E, Sanders GM, Au TK, Hung CT. Radial nerve injury after intravenous cannulation at the wrist--a case report. *Ann Acad Med Singapore* 1999; 28: 288-9.
31. Stahl S, Kaufman T, Ben-David B. Neuroma of the superficial branch of the radial nerve after intravenous cannulation. *Anesth Analg* 1996; 83: 180-2.
32. Boeson MB, Hranchook A, Stoller J. Peripheral nerve injury from intravenous cannulation: a case report. *AANA J* 2000; 68: 53-7.
33. Sawaizumi T, Sakamoto A, Ito H. Injury of superficial radial nerve on the wrist joint induced by intravenous injection. *J Nippon Med Sch* 2003; 70: 355-9.
34. Horowitz SH. Peripheral nerve injury and causalgia secondary to routine venipuncture. *Neurology* 1994; 44: 962-4.
35. Kim KH, Byun EJ, Oh EH. Ultrasonographic findings of superficial radial nerve and cephalic vein. *Ann Rehabil Med* 2014; 38: 52-6.
36. Kim JS, Yoo SH, Chung ME, Oh JS, Cho DW, Choi GH. Superficial radial nerve and cephalic vein: an anatomic study by cadaver dissection. *J Korean Acad Rehabil Med* 2010; 34: 394-6.
37. Asheghan M, Khatibi A, Holisaz MT. Paresthesia and forearm pain after phlebotomy due to medial antebrachial cutaneous nerve injury. *J Brachial Plex Peripher Nerve Inj* 2011; 6: 5.
38. Stevens RJ, Mahadevan V, Moss AL. Injury to the lateral cutaneous nerve of forearm after venous cannulation: a case report and literature review. *Clin Anat* 2012; 25: 659-62.
39. Ramos JA. Venipuncture-related lateral antebrachial cutaneous nerve injury: what to know? *Braz J Anesthesiol* 2014; 64: 131-3.
40. Rayegani SM, Azadi A. Lateral antebrachial cutaneous nerve injury induced by phlebotomy. *J Brachial Plex Peripher Nerve Inj* 2007; 2: 6.
41. Horowitz SH. Venipuncture-induced causalgia: anatomic relations of upper extremity superficial veins and nerves, and clinical considerations. *Transfusion* 2000; 40: 1036-40.
42. Yamada K, Yamada K, Katsuda I, Hida T. Cubital fossa venipuncture sites based on anatomical variations and relationships of cutaneous veins and nerves. *Clin Anat* 2008; 21: 307-13.
43. Sin JY, Kim DH, Bun HR, Hwang MR, Kang YK, Kwon HK, et al. Anatomical considerations of lateral and medial antebrachial cutaneous nerves. *J Korean Acad Rehabil Med* 2007; 31: 329-32.
44. World Health Organization. WHO guidelines on drawing blood: best practices in phlebotomy. 2010. Available from http://www.euro.who.int/__data/assets/pdf_file/0005/268790/WHO-guidelines-on-drawing-blood-best-practices-in-phlebotomy-Eng.pdf?ua=1.
45. Gentili F, Hudson AR, Kline D, Hunter D. Early changes following injection injury of peripheral nerves. *Can J Surg* 1980; 23: 177-82.