5-1-2017

The Use of Intraosseous Needles for Injection of Contrast Media for Computed Tomographic Angiography of the Thoracic Aorta

Michael A. Winkler
University of Kentucky, michael.winkler@uky.edu

Cynthia Talley
University of Kentucky, c.talley@uky.edu

Connor Woodward
University of Kentucky, connor.woodward@uky.edu

Alexander Kingsbury
University of Kentucky, a.kings@uky.edu

Frank Appiah
University of Kentucky, frankappiah11@gmail.com

See next page for additional authors

Authors
Michael A. Winkler, Cynthia Talley, Connor Woodward, Alexander Kingsbury, Frank Appiah, Hossam Elbelasi, Kevin P. Landwehr, Xingzhe Li, and Dominik Fleischmann

The Use of Intraosseous Needles for Injection of Contrast Media for Computed Tomographic Angiography of the Thoracic Aorta

Notes/Citation Information
Published in *Journal of Cardiovascular Computed Tomography*, v. 11, issue 3, p. 203-207.

Digital Object Identifier (DOI)
https://doi.org/10.1016/j.jcct.2017.03.001

Journal of Cardiovascular Computed Tomography 11 (2017) 203–207

Contents lists available at ScienceDirect

Journal of Cardiovascular Computed Tomography

journal homepage: www.JournalofCardiovascularCT.com

Technical report

The use of intraosseous needles for injection of contrast media for computed tomographic angiography of the thoracic aorta

Michael Winkler, MD [a, b, *], Cynthia Talley, MD [c], Connor Woodward [a], Alexander Kingsbury [a], Frank Appiah [a], Hossam Elbelasi, MD [a, b], Kevin Landwher [a], Xingzhe Li [a], Dominik Fleischmann, MD [d]

[a] Department of Radiology, University of Kentucky, Lexington, KY, USA
[b] Division of Cardiovascular Medicine, Department of Internal Medicine, University of Kentucky, Lexington, KY, USA
[c] Department of Surgery, University of Kentucky, Lexington, KY, USA
[d] Department of Radiology, Stanford University, Stanford, CA, USA

ARTICLE INFO

Article history:
Received 7 October 2016
Received in revised form
8 March 2017
Accepted 12 March 2017
Available online 16 March 2017

Keywords:
Intraosseous needle
Computed tomography
Angiography
Thoracic aorta
Traumatic aortic injury
Emergency radiology
Injection
Contrast media

ABSTRACT

Background: The objective of this study is to evaluate the safety and quality of computed tomographic angiography of the thoracic aorta (CTA-TA) exams performed using intraosseous needle intravenous access (ION-IVA) for contrast media injection (CMI).

Methods: All CTA-TA exams at the study institution performed between 1/1/2013 and 8/14/2015 were reviewed retrospectively to identify those exams which had been performed using ION-IVA (ION-exams). ION-exams were then analyzed to determine aortic attenuation and contrast-to-noise ratio (CNR). Linear regression was used to determine how injection rate and other variables affected image quality for ION-exams. Patient electronic medical records were reviewed to identify any adverse events related to CTA-TA or ION-IVA.

Results: 17 (~0.2%) of 7401 exams were ION-exams. ION-exam CMI rates varied between 2.5 and 4 ml/s. Mean attenuation was 312 HU (SD 88 HU) and mean CNR was 25 (SD 9.9). A strong positive linear association between attenuation and injection rate was found. No immediate or delayed complications related to the ION-exams, or intraosseous needle use in general, occurred.

Conclusion: For CTA-TA, ION-IVA appears to be a safe and effective route for CMI at rates up to 4 ml/s.

1. Introduction

The majority of victims of major trauma require computed tomographic angiography of the thoracic aorta (CTA-TA) as part of their imaging evaluation.[1] CTA-TA requires intravenous access (IVA) for contrast media injection (CMI) at high flow rates.[2] Peripheral IVA is favored for this purpose, but is not always achievable.[2] In such circumstances, central lines can be used for CMI.[2] In instances when central line placement is inexpedient or impossible, an alternative exists: intraosseous needle intravenous access (ION-IVA) (see Figs 1 and 2). ION-IVA placement is safer and faster than central line placement, with a failure rate of less than 1%.[3]

A recent clinical review by Baadh et al. calls for imaging physicians to familiarize themselves with the technique of using ION-IVA for CMI.[4] There is a substantial body of mid twentieth century literature, predating the advent of computed tomography, reporting the safe use of ION-IVA for CMI during fluoroscopic venography studies.[5] Fairly recent data on the safe use of ION-IVA for CMI from animal models has also been published.[6,7] However, modern literature reporting the clinical use of ION-IVA for CTA-TA is sparse.[4,8–10] The objective of this study was to retrospectively survey the safety of ION-IVA CMI performed during CTA-TA and to

Abbreviations: CTA-TA, computed tomographic angiography of the thoracic aorta; IVA, intravenous access; CMI, contrast media injection; *P*-IVA, peripheral intravenous access; ION-IVA, intraosseous needle intravenous access; ION-exams, examinations performed using ION-IVA; CNR, contrast-to-noise ratio.

* Corresponding author. University of Kentucky, 800 Rose Street, Room HX-313A, Lexington, KY, 40536-0293, USA.
E-mail address: michael.winkler@uky.edu (M. Winkler).

http://dx.doi.org/10.1016/j.jcct.2017.03.001

assess the quality of the resultant exams.

2. Materials and methods

7401 CTA-TA exams, performed between January 1, 2013 and August 14, 2015, were reviewed to create a CTA-TA database. Written informed consent was waived by the Institutional Review Board due to the retrospective nature of the project and because of the large number of exams included in the database. CTA-TA quality measurements were performed from survey series of 3.0 mm thick images. Attenuation and noise were measured within the ascending aorta and nearby adipose tissue using circular region-of-interests of approximately 100 mm.[2] Contrast-to-noise ratio (CNR) for the aorta was derived using the method of Feuchtner et al.[11] Other CTA-TA data collected included technical factors such as site of IVA, CMI rate, CMI dose, scanner type, and reconstruction method. Patient data, such as age, sex, weight, height, and chest width, was collected. The institutional adverse event reporting system was queried for all events related to CTA-TA. Complete chart review was performed for all patients who received CTA-TA exams utilizing ION-IVA.

Statistical analyses were performed using open source "R" statistical software version 3.1.1. Scatterplots and correlation coefficients were used to examine adequacy of a linear association between CNR and covariates of interest. The potential of multicollinearity was assessed with the Pearson correlation coefficient. Multiple linear regression models were fitted with two-way interactions. Backward elimination procedure, F-statistic, and adjusted R squared were used to select parsimonious models. Constant variance, normality, and independence were examined.

3. Results

17 (~0.2%) of 7401 of the exams performed during the study period utilized ION-IVA. All ION-exams were performed with EZ-IO needles (Teleflex Medical, Limerick, Pennsylvania, U.S.A.). CMI rates for ION-exams varied between 2.5 and 4.0 ml/s (mean of 3.4 ml/s). CMI dose varied between 80 and 100 ml (mean of 91 ml) of Iohexol 350. Mean attenuation for the ION-exams was 312 HU (SD 88 HU) and mean CNR was 25 (SD 9.9). Assessment of attenuation versus other covariates revealed a strong positive linear association between attenuation and CMI rate ($R = 0.58$, p-value $= 0.014$) and a strong negative association between attenuation and chest width ($R = -0.53$, p-value $= 0.028$). CNR also exhibited a strong negative linear association with chest width ($R = -0.77$, p-value<0.001). ION-exam and patient data is summarized in Table 1. Representative images from exemplary ION-exams are presented in Fig. 2 (and GIFs 1 and 2 online).

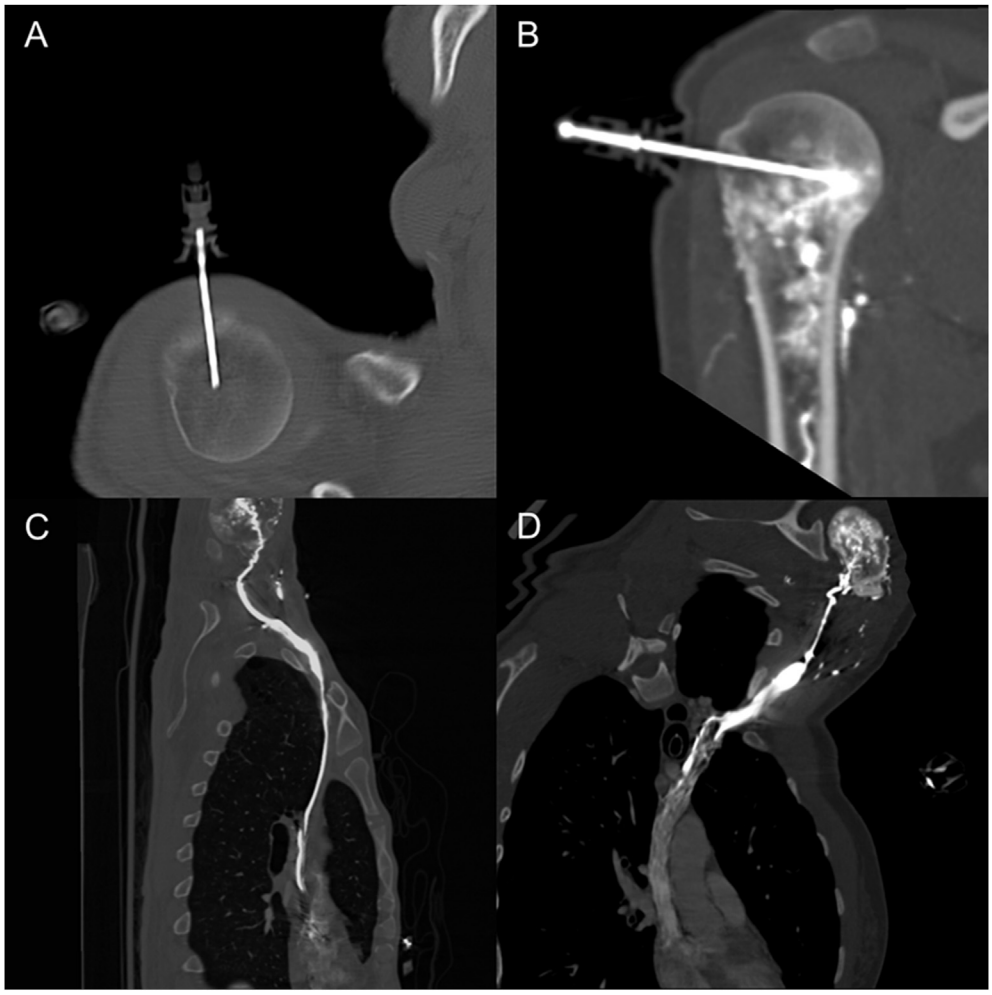

Fig. 1. A) MPR image derived from a preliminary scan performed to check intraosseous needle position. B) Thin MIP image derived from a scan showing an intraosseous needle and contrast media within the intramedullary space. C) CPR image showing path of contrast media from right humerus to the right atrium. D) Path of contrast from the left humerus.

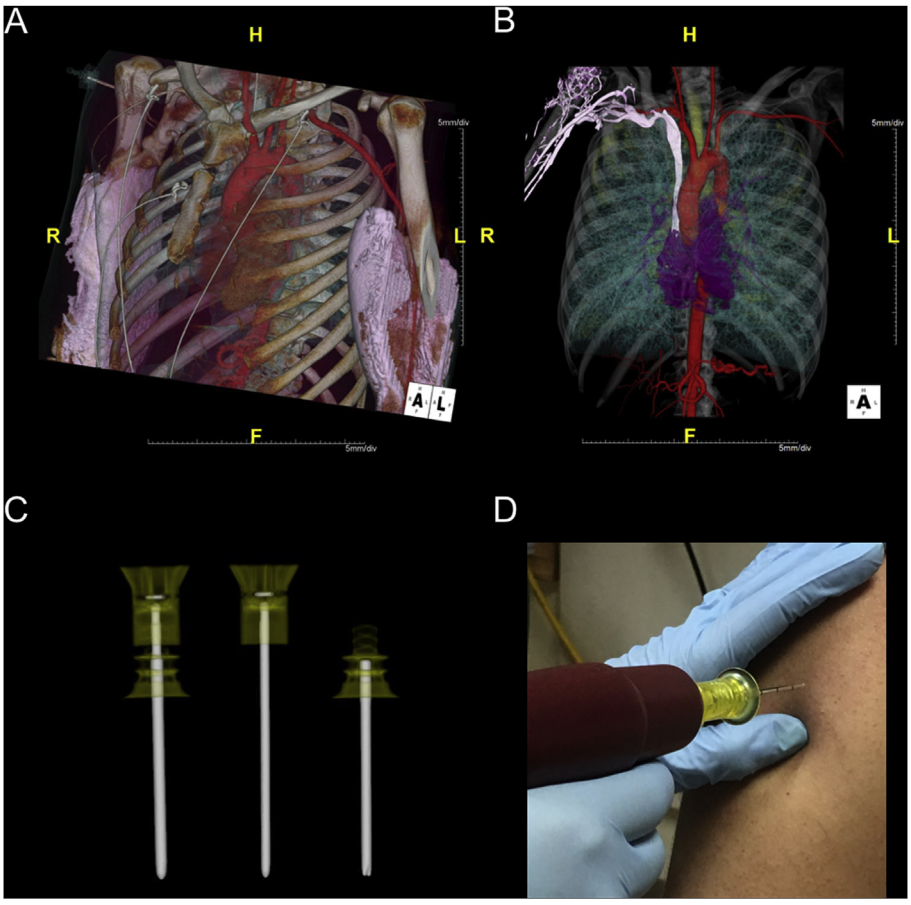

Fig. 2. A) VR image of data from an ION-exam. Note that there is bilateral extravasation from two injection attempts via antecubital IVA. In this case, ION-IVA was used to salvage the study. B) VR image of data from a different ION-exam. Note that in this case the post contrast media saline flush was not adequate and there is residual contrast within the venous system. The image demonstrates the relationship of the intramedullary space to the veins of the upper extremity. C) Volume Rendering of data from a scan of two intraosseous needle sets, one with the trocar in place and the other with the trocar beside the needle. D) Intraosseous needle loaded on a needle driver and ready for insertion.

Table 1
Data related to CTA-TA exams performed with ION-IVA.

Case Number	Injection Rate (cm/s)	Contrast Media Dose (mL)	ION site	kVp	mAs	CTDIvol (mGy)	DLP (mGy*cm)	Scanner Model	A AA (HU)	N AA (HU)	A F (HU)	CNR AA	History	Age	Sex	Body Mass Index	Chest Width (cm)	Disposition
1	2.5	100	RH	120	253	17	446	S40	136	18	−52	10	assault	23	M	26	42	expired
2	2.7	100	RH	120	279	23	492	S40	233	16	−112	22	fall	88	F	33	46	rehab
3	3	100	RH	120	202	17	461	S40	250	21	−113	17	MVC	48	F	29	42	home
4	3	100	LT	120	200	16	341	S40	239	18	−109	19	MVC	51	F	30	42	expired
5	3	100	RH	120	185	15	331	S40	308	13	−95	31	assault	23	M	18	33	rehab
6	3.5	80	RH	120	154	13	371	S40	434	11	−91	48	EXP	32	M	17	32	rehab
7	3.2	100	LT	100	130	5	145	Edge	254	12	−83	28	MVC	27	M	20	32	home
8[a]	3.5	100	LH	120	192	16	377	S40	396	20	−88	24	GSW	21	M		35	expired
9	3.5	80	LH	120	206	17	292	S40	299	21	−103	19	fall	40	F	28	45	home
10	3.5	100	LH	120	149	12	345	S40	407	14	−100	36	MVC	26	F	23	29	home
11	3.5	80	LH	100	140	6	118	Edge	367	18	−117	27	fall	47	M	23	31	home
12	3.5	80	RH	120	235	15	370	Edge	260	10	−127	39	MVC	24	M	28	35	home
13	3.5	80	RH	120	197	16	357	S40	235	37	−107	9	MVC	34	M	27	47	home
14	4	80	RH	120	200	16	336	S40	374	23	−96	20	MVC	23	F	35	45	home
15	4	90	LH	120	192	16	396	S40	456	18	−91	30	MVC	27	F	26	37	expired
16	4	100	RH	120	204	17	395	S40	272	20	−108	19	GSW	62	F	29	46	home
17	4	80	RH	100	227	9	201	Edge	381	19	−120	26	GSW	28	M	23	35	home
mean	3.41	91		116	197	14	339		311	18	−101	25		37		26	38	
SD	0.46	9.9		7.9	39	4.4	102		88	6	17	10		18		5	6	

Abbreviations: ION = intraosseous needle, CTDIvol = volume computed tomography dose index, DLP = dose length product, HU = Hounsfield units, S40 = Siemens Sensation 40 ERCT, Edge = Siemens Somatom Definition Edge, A = attenuation, AA = ascending aorta, N = noise, F = fat, RH = right humerus, LH = left humerus, LT = left tibia, MVC = motor vehicle collision, EXP = explosion, GSW = gunshot wound, M = male, F = female, CNR = contrast to noise ratio, rehab = rehabilitation facility, SD = standard deviation.

[a] Height and weight data was not recorded for this patient. In all cases the contrast media, Iohexol 350, was injected at room temperature.

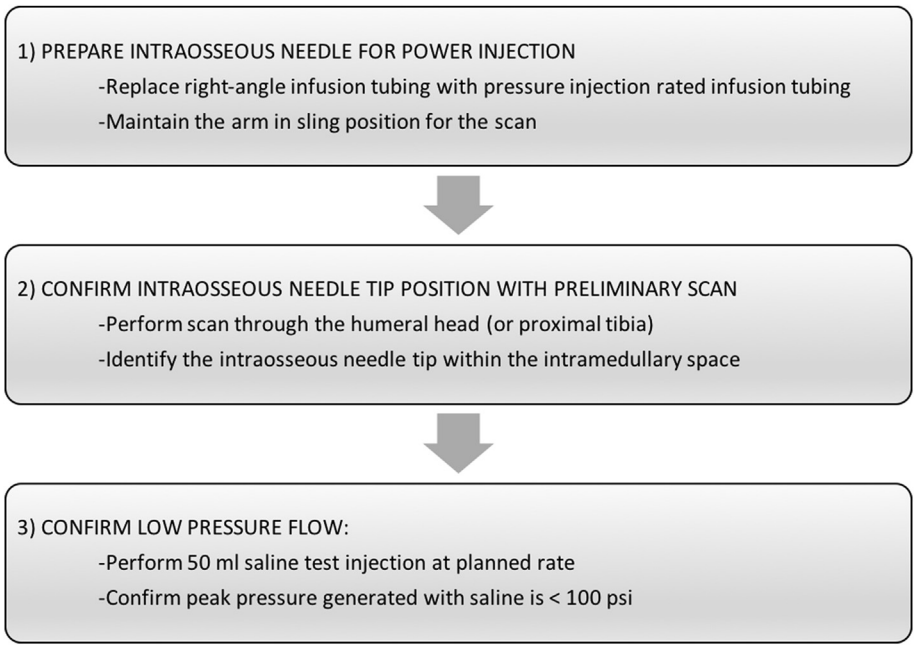

Fig. 3. Algorithm to confirm suitability of ION-IVA for CM injection.

No extravasation events related to CMI via ION-IVA occurred. However, it is interesting to note that two patients received ION-IVA CMI after extravasations related to antecubital IVA (for example see Fig. 1a, GIF 2). A complete review of ION-exam patient records failed to reveal any evidence of ION-IVA related complication. Specifically, there were no reports of ION-IVA placement failure, functional failure, bone marrow aspiration difficulty, damage to the ION-IVA, aborted CTA-TA exam, extravasation, patient discomfort, fracture, infection, fat embolism, bone infarction, or manifestation of compartment syndrome.

4. Discussion

The use of ION-IVA for CTA-TA during the study period was rare, occurring in only 17 (0.2%) of the 7401 exams performed. (central lines, in contrast, were utilized in 125). This rarity may reflect trepidation of imaging personnel who were confused by or unfamiliar with ION-IVA. However, the study institution has developed a useful algorithm (Fig. 3) for using ION-IVA for CMI. As this and other algorithms[4] are promulgated via the medical literature, training in the use ION-IVA for CTA-TA may become routine. Furthermore, it is promising that in this series no untoward event related to CMI via ION-IVA was observed. As this and similar evidence[4,8–10] related to the safety of ION-IVA for CMI mounts, personnel may be less reluctant to use ION-IVA for this indication.

The mean aortic attenuation observed in the ION-exams was 312 HU, exceeding the mean attenuation of exams in the database performed with antecubital access, which was 271 HU. Due to the small sample size of ION-exams, this result should not be considered significant. The ION-exam data demonstrated statistically significant positive linear associations between aortic attenuation and CMI rate. The implication of this association is that, although the vascular anatomy of bone differs from that of superficial soft tissue, these differences do not limit flow, at least for rates less than 4.0 ml/s. Further study will be necessary to determine if this holds true for higher injection rates (e.g. the 5.0–6.0 ml/s rates recommended for cardiac CT).

Intramedullary bone is rich in pain receptors, and there is both the potential for, and anticipation of, pain during prolonged ION-IVA infusions.[3,12] While it is interesting that during this review no reports of ION-IVA related pain were found, it is important to note that all of the patients studied were either experiencing pain associated this their traumatic injuries, the recipients of IV analgesia, or obtunded at the time of CTA-TA acquisition. Consequentially, pain from their ION-IVA infusions may have been masked or simply not recorded. Prophylactic analgesia is recommended when ION-IVA is used for large volume infusions.[3]

4.1. Limitations and bias

This study has notable limitations. It is a single institution observational study that yielded a very small sample size (N = 17). Patients with difficult AC-IVA often suffer from cardiovascular insufficiency, which may have introduced susceptibility bias. Technologist unfamiliarity with ION likely lead to selection bias and may explain the small sample size of this study.

5. Conclusion

The data presented herein suggests ION-IVA may be an acceptable alternative route for CMI for CTA-TA when peripheral IVA is unavailable or inexpedient. Prospective studies should be performed to validate this finding.

6. Summary

This study investigated the safety and quality of intraosseous needle intravenous access for contrast injection for Computed Tomographic Angiography of the Thoracic Aorta. A retrospective search of a quality and safety database found 17 studies performed in this manner. A control group, comprised of the studies in the database performed with antecubital intravenous access, was used for comparison. The quality metrics of the two groups were similar, with the intraosseous needle group being slightly better. A review of patient and complication records found no evidence of complications related to intraosseous needle use.

Role of funding sources

The work was supported by a grant from Teleflex Incorporated and by NIH grant 8UL1TR000117. Teleflex received a draft of the manuscript prior to submission but had no role in the study or editorial privilege.

Conflict of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jcct.2017.03.001.

References

1. Fox N, Schwartz D, Salazar JH, et al. Evaluation and management of blunt traumatic aortic injury: a practice management guideline from the eastern association for the surgery of trauma. *J Trauma Acute Care Surg*. 2015 Jan;78:136–146. http://dx.doi.org/10.1097/TA.0000000000000470. PMID: 25539215.
2. Bae KT. Intravenous contrast medium administration and scan timing at CT: considerations and approaches. *Radiology*. 2010 Jul;256:32–61. http://dx.doi.org/10.1148/radiol.10090908. PMID: 20574084.
3. Petitpas F, Guenezan J, Vendeuvre T, Scepi M, Oriot D, Mimoz O. Use of intra-osseous access in adults: a systematic review. *Crit Care*. 2016 Apr 14;20:102. http://dx.doi.org/10.1186/s13054-016-1277-6. PMID: 27075364.
4. Baadh AS, Singh A, Choi A, Baadh PK, Katz DS, Harcke HT. Intraosseous vascular access in radiology: review of clinical status. *AJR Am J Roentgenol*. 2016 May 10:W1–W7 [Epub ahead of print] PMID: 27164302.
5. Schobinger RA. *Intra-osseous Venography*. New York: Grune & Stratton; 1960.
6. Günal I, Köse N, Gürer D. Compartment syndrome after intraosseous infusion: an experimental study in dogs. *J Pediatr Surg*. 1996 Nov;31:1491–1493. PMID: 8943107.
7. Cohen J, Duncan L, Triner W, Rea J, Siskin G, King C. Comparison of computed tomography image quality using intravenous vs. Intraosseous contrast administration in swine. *J Emerg Med*. 2015 Nov;49:771–777. http://dx.doi.org/10.1016/j.jemermed.2014.06.036. PMID: 26072318.
8. Knuth TE, Paxton JH, Myers D. Intraosseous injection of iodinated computed tomography contrast agent in an adult blunt trauma patient. *Ann Emerg Med*. 2011 Apr;57:382–386. http://dx.doi.org/10.1016/j.annemergmed.2010.09.025. PMID: 21111513.
9. Ahrens KL, Reeder SB, Keevil JG, Tupesis JP. Successful computed tomography angiogram through tibial intraosseous access: a case report. *J Emerg Med*. 2013 Aug;45:182–185. http://dx.doi.org/10.1016/j.jemermed.2012.11.091. PMID: 23726677.
10. Budach NM, Niehues SM. CT angiography of the chest and abdomen in an emergency patient via humeral intraosseous access. *Emerg Radiol*. 2016:1–4 [Epub ahead of print] PMID: 27572932.
11. Feuchtner GM, Jodocy D, Klauser H, et al. Radiation dose reduction by using 100-kV tube voltage in cardiac 64-slice computed tomography: a comparative study. *Eur J Radiol*. 2010 Jul;75:e51–56. http://dx.doi.org/10.1016/j.ejrad.2009.07.012. PMID: 19671491.
12. Mach DB, Rogers SD, Sabino MC, et al. Origins of skeletal pain: sensory and sympathetic innervation of the mouse femur. *Neuroscience*. 2002;113:155–166. PMID: 12123694.