LOWER MAINLAND MEDICAL IMAGING
STAFF EDUCATION

Contrast Administration: Intraosseous Route



Contrast Administration: Intraosseous Route – Staff Education

Table of Contents

Introduction....3
Anatomy and Physiology....4
Image of Magnified Osteon....4
Images of the Structural Components of Bone....4
Image of the Upper Humerus and Chest: Contrast Media Flow Injected via IO into the Proximal Humerus....5
Images of Knee: Contrast Media Flow Injected via IO into the Proximal Tibia....5
Image of Abdomen, Pelvis and Femur: Contrast Media Flow Injected via IO into the Proximal Tibia....6
Equipment and Supplies....7
Image of B.I.G. Needles for Adult and Pediatric
Images of EZ-IO Needles
Contrast Media Injection Protocol....7
Image of Injector Module Screen....8
Assessment of Intraosseous Needle Placement....8
Images of Correct Placement: Proximal Humerus....8
Images of Correct Placement: Proximal Tibia....9
Complications of Intraosseous Needle Insertion and Contrast Administration....9
Dislodgement....10
Extravasation....10
Emboli....11
Osteomyelitis....11
Images of Osteomyelitis....11
Documentation....12
Exam Data....12
Accession/Encounter #....12
Date of Exam....12
Mnemonics....12
Contrast Administration Data....12
Contrast Type....12
Flow Rate....12
Injection Volume....12
IO Needle Site and Side....12
Peak Contrast (HU)....12
Time to Peak....12
Images of graphs illustrating the peak Hounsfield Units and time of contrast injection....13
Injection Pressure (PSI)....13
Image of Injector Module Graph....13
Image of Secondary Capture sent to PACS....13
Scan Acquisition Parameters....14
kVp....15
mAs (effective)....15
$CTDI_{vol}$....15
DLP....15
Intraosseous (IO) Injection Success....15
Record of Intraosseous Injections of Contrast Media in CT....15
IO Contrast Administration Checklist....16
References....17
Definitions....18
Approval....19

Contrast Administration: Intraosseous Route – Staff Education

Introduction

In British Columbia, healthcare workers respond to medical and traumatic emergencies and need to establish vascular access to administer blood, intravenous fluids and medication. The preferred access is via a peripheral intravenous (PIV) line in the arm. In some emergent clinical scenarios, establishing an intraosseous infusion site in the intramedullary space may be the only available route. This practice is supported in The 2019 Canadian Vascular Access Association guidelines stating to "consider use of IO route if vascular access is not available or cannot be obtained."

Only personnel trained in the insertion, manipulation, and or care and maintenance of IO needles are authorized to use these devices. In pre-hospital settings, BC Emergency Health Services paramedics receive special training to be able to insert intraosseous needles. In acute care hospitals, the clinical team, made up of physicians, nurse practitioners (NP), anesthesia assistants, and nurses (RN) also complete education and training to be able to insert IO needles as well as provide care and maintenance. In Medical Imaging, radiologists, nurses and technologists do not receive training in insertion techniques, care or maintenance of IO needles and is considered out of scope

The use of IO needles is intended in emergent, resuscitative and trauma situations when vascular access is not available or cannot be obtained. The decision to use the IO route for contrast administration should be made jointly by the responsible radiologist and the clinical team. The two preferred intraosseous infusion sites compatible for power injections of iodinated contrast media are the proximal humerus and the proximal tibia.

Patients should arrive to the Medical Imaging department with an IO needle already in place. The two preferred intraosseous infusion sites for power administration of iodinated contrast media are the proximal humerus and proximal tibia. Prior to contrast administration, the radiologist should perform a radiographic assessment of the long bone the IO needle is in for fractures via scout image(s) and confirm IO placement and position with a limited unenhanced CT scan of the IO needle site prior to contrast administration.

For conscious and alert patients who are responsive to pain stimuli, the clinical team should consider IO anesthetic. If IO anesthetic is initiated, it is recommended that it be given prior to power administration of contrast media.

MRT's must ensure a new, single use pressure rated tubing extension set with two (2) back-check valves is used for the administration of contrast media via IO needle. Only power compatible tubing should be used for the administration of contrast media via a power injector. Failure to use a power compatible extension set may cause damage to the IO needle and or harm to the patient. All complications or adverse events related to contrast administration via the IO needle must be reported to the responsible radiologist and clinical team member(s) as well as entered in the health authority Patient Safety and Learning System (PSLS).

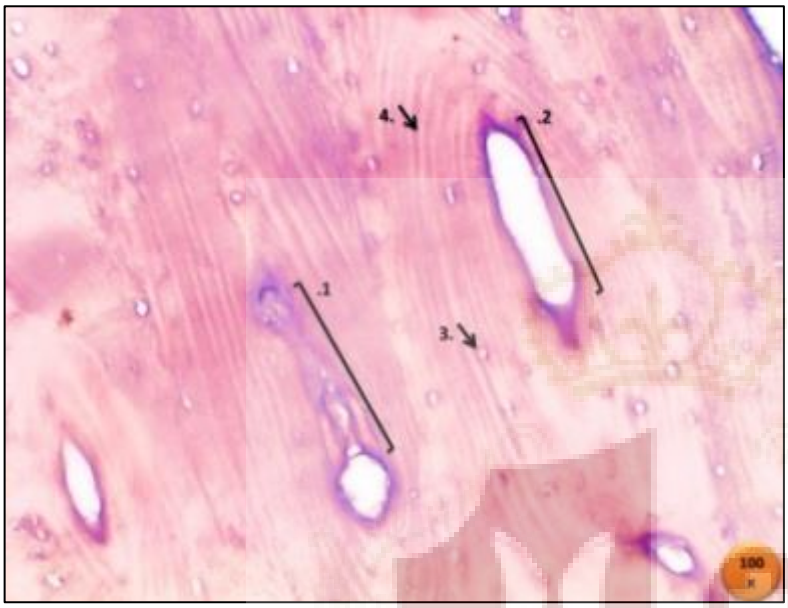
Pre-contrast test injection using normal saline 0.9% (NS) should be performed and be free of complications prior to power administration of contrast. All complications or adverse event related to the pre-contrast saline flush must be immediately communicated to the responsible radiologist and clinical team member(s). If no complications or adverse events occur, proceed to contrast administration. Following contrast administration, a post-contrast normal saline 0.9% (NS) flush should be done as part of the contrast media injection protocol.

Contrast Administration: Intraosseous Route – Staff Education

Anatomy and Physiology

During IO infusion, within the epiphysis of the intramedullary space contrast media travels quickly through a network of blood vessels, sinusoids, Haversian canals, and Volkmann canals. Together, the system of structures form Osteons, the structural components of cortical bone. Contrast then moves out of these nutrient and emissary vessels and into the central circulation.[7]

Image of Magnified Osteon



1 Volkmann's Canal

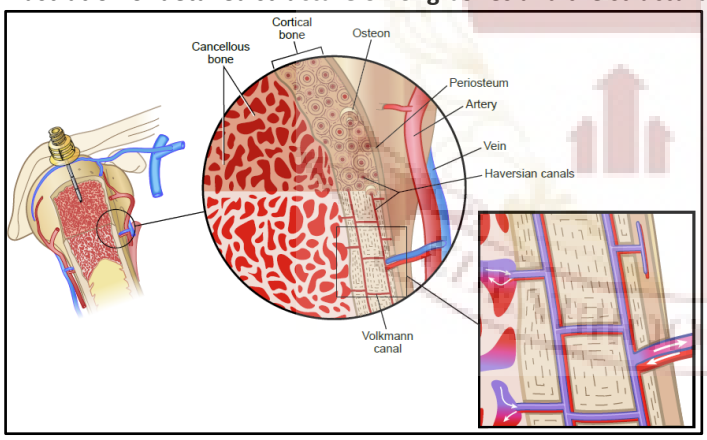
2 Haversian canal

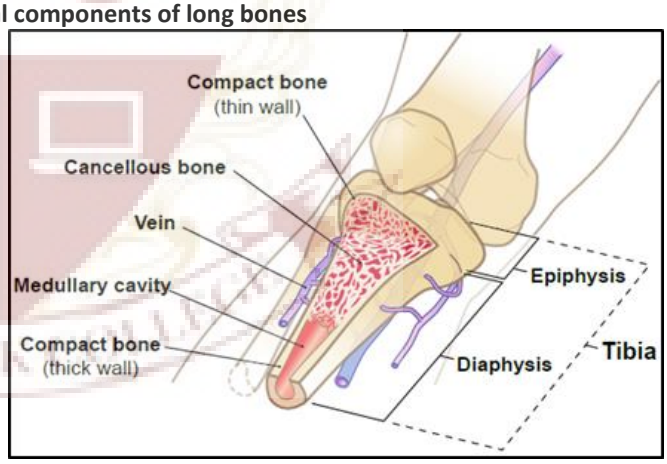
3 Lacunae

4 Lamellae

Image courtesy of Guido Fregapani - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=37113850

Illustration of detailed structure of long bones and the structural components of long bones





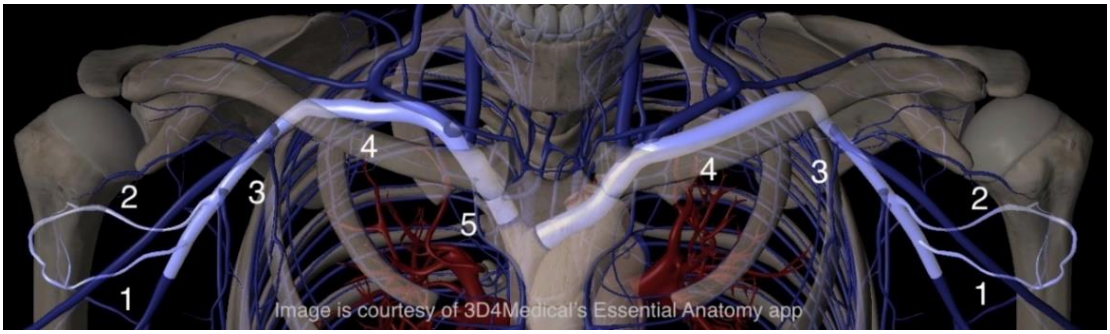
Images courtesy of Arrow EZ-IO® Teleflex, Wayne PA

In the humerus, contrast media reaches the central circulation via the Anterior and Posterior Circumflex Humeral Veins. From there, blood empties into the Axillary Vein and then the Subclavian Vein. On the right side, returning blood will first empty from the Subclavian Vein into the Brachiocephalic Vein before returning to the right Atrium in the heart.

In the tibia, contrast media from an intraosseous injection collects in the emissary vessels and empties into the Popliteal Veins[2]. After entering the Popliteal Veins, blood travels superiorly to the Femoral Veins, External Iliac Veins, and Common Iliac Veins before joining the Inferior Vena Cava and entering the right atrium of the heart.

Contrast Administration: Intraosseous Route – Staff Education

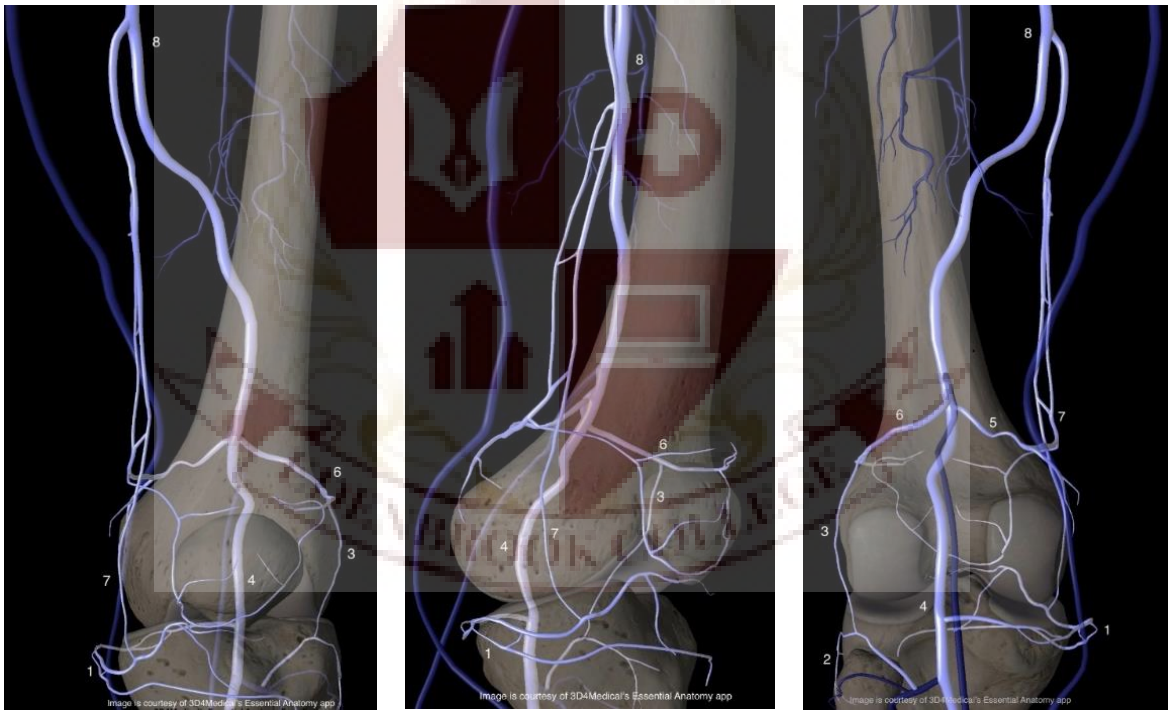
Drainage of Contrast Media via Intraosseous Needle in the Proximal Humerus



1 Anterior Circumflex Humeral Vein	4 Subclavian Vein
2 Posterior Circumflex Humeral Vein	5 Brachiocephalic Vein
3 Axillary Vein	

Drainage of Contrast Media via Intraosseous Needle in the Proximal Tibia

AP View | **Lateral Oblique View** | **Posterior View**



1 Inferior Medial Genicular Vein	2 Inferior Lateral Genicular Vein
3 Communicating Branch of Lateral Genicular Vein	4 Popliteal Vein
5 Superior Medial Genicular Vein	6 Superior Lateral Genicular Vein
7 Descending Genicular Vein	8 Femoral Vein

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Drainage of Contrast Media via Intraosseous Needle in the Proximal Tibia



1 Inferior Vena Cava	2 Common Iliac Vein	3 Exterior Iliac Vein
4 Femoral Vein	5 Popliteal Vein	6 Inferior Lateral Genicular Vein
7 Inferior Medial Genicular Vein		

Contrast Administration: Intraosseous Route – Staff Education

Equipment and Supplies

1. Contrast Media Power Injector
2. Intraosseous Needle system (see examples below of common IO devices used)

Bone Injection Gun (B.I.G.)



B.I.G. images courtesy of PerSysMedical / Houston, TX

EZ-IO

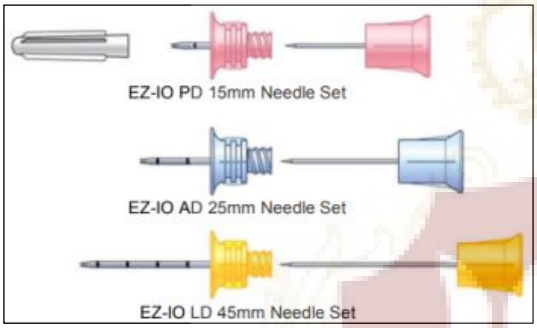
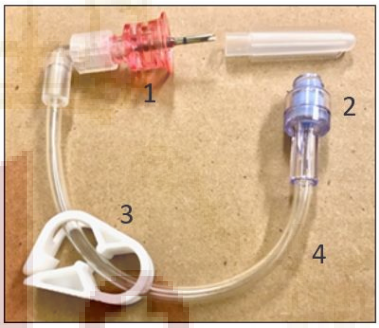


Image courtesy of Vidacare / Teleflex



1. IO needle hub
2. Needleless connection
3. Clamp
4. IO needle extension tubing (non-power compatible)

3. Power compatible extension set appropriate for Medical Imaging use rated for a minimum of 300 PSI.
    a) Medical Systems: TR-60 2B/C or approved equivalent sub
    b) Canadian Hospital Specialties: 10-1244 or approved equivalent sub

Contrast Media Injection Protocol

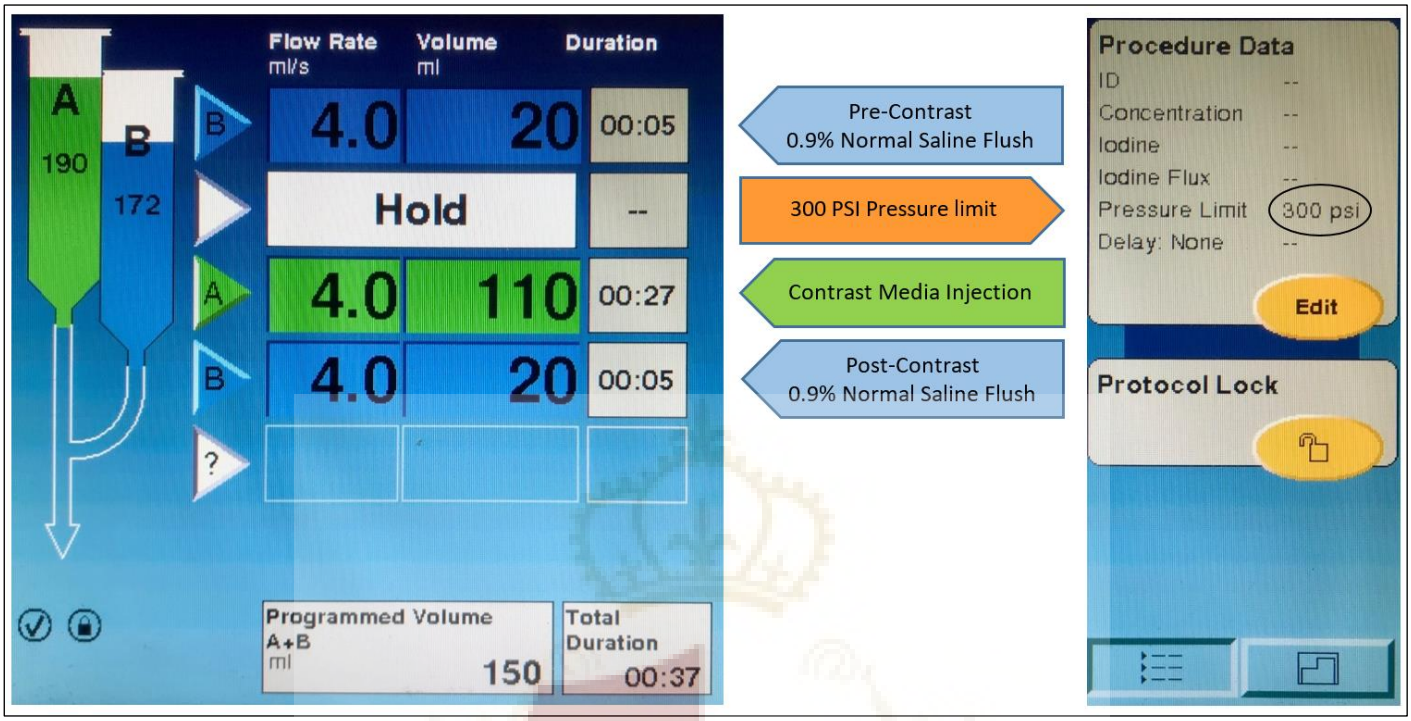
Contrast media injectors are complex mechanical machines capable of holding over 100 different injection protocols used in the CT environment. Injection protocols can be designed to administer iodinated contrast media, normal saline (NS) or a mixture of both for specific CT examinations.

CT contrast media injection protocols include a pre-contrast normal saline 0.9% flush. This is done to assess if the vein can tolerate the contrast flow rate. If adequate, the MRT administers a timed or tracked bolus of contrast media followed by a post-contrast 0.9% normal saline flush. Flow rates for contrast media and normal saline via an IO needle are similar to those used via a peripheral intravenous (PIV) catheter.

The image below identifies the different stages of an injection protocol. Details of the prescribed flow rates and volumes of saline (blue) and contrast (green) injections parameters of a typical protocol are included, as well as the pressure limits set for the injection. The majority of literature indicates iodinated contrast media has been successful administered via intraosseous needles at injection rates between 2.0 – 4.0 mLs/second. Based on the literature, recommended flow rates of contrast media and normal saline 0.9% via an intraosseous needle should not exceed 4 mLs/second and a pressure limit set at 300 PSI.

Contrast Administration: Intraosseous Route – Staff Education

Injector Module Screen

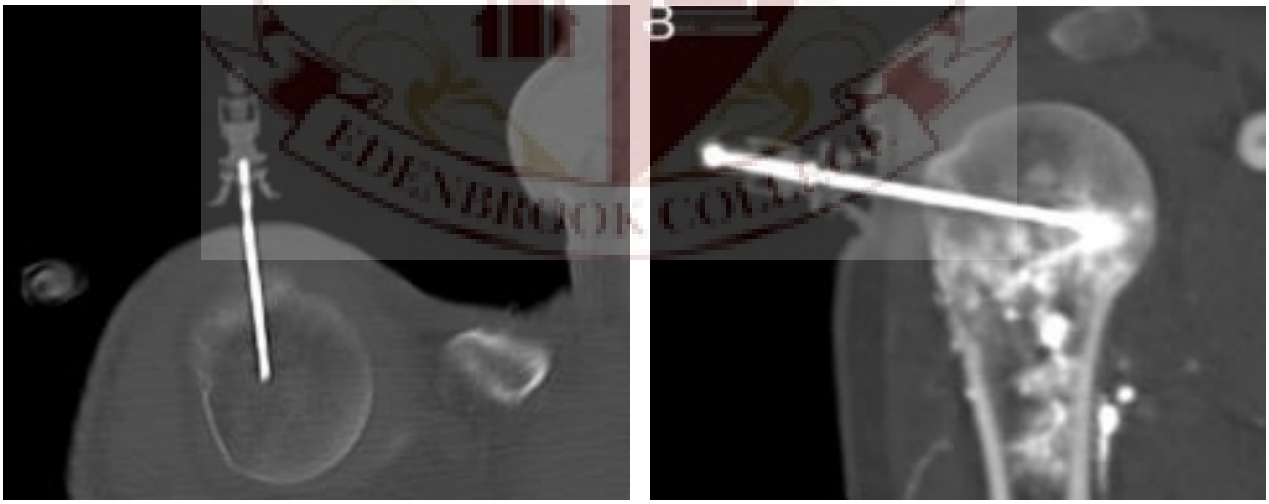


Assessment of Intraosseous Needle Position and Placement

Correct Placement

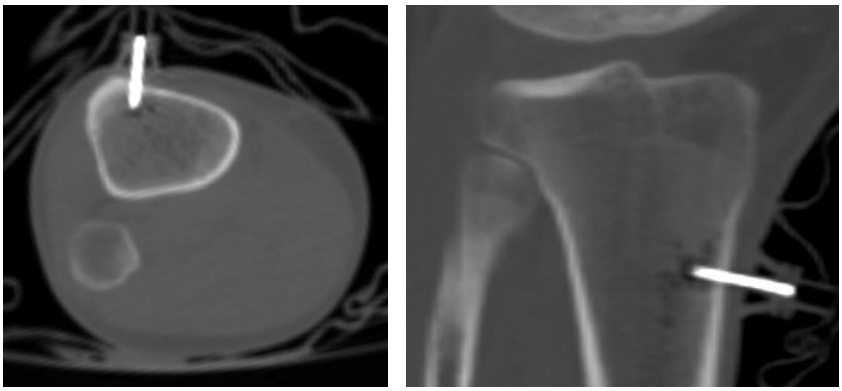
The following images show correct placement and position of intraosseous needle in the intramedullary space of the two preferred sites in the (1) proximal humerus and (2) proximal tibia.

1. Multiplanar images of correct intraosseous needle placement and position in the proximal humerus.



Images courtesy of Michael Winkler, Talley C. The use of intraosseous needles for injection for computed tomography of the thoracic aorta. Journal of Cardiovascular Computed Tomography 11 (2017)203-207.

2. Multiplanar images of correct intraosseous needle placement and position in the proximal tibia.



Images courtesy of Harcke, Theodore COL H et al. Placement of Tibial Intraosseous Infusion Devices. Military Medicine 2011, 176 7:824

Incorrect Placement

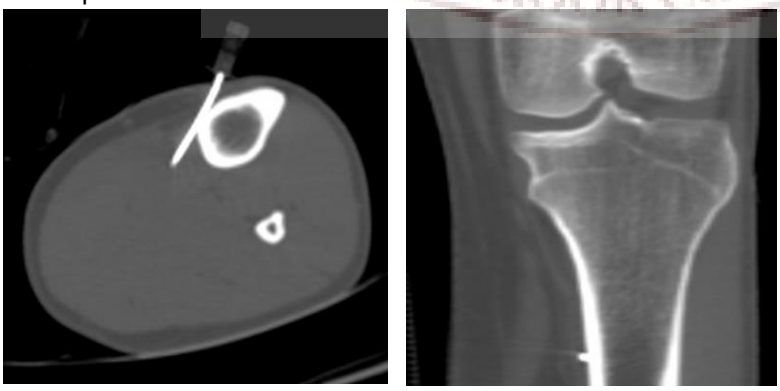
Images 3 and 4 are examples of incorrect or poorly placed intraosseous needles where consideration should be given to re-insert or manipulate the device prior to contrast media administration

1. Multiplanar and 3D reconstruction of an intraosseous needle poorly positioned against the inner cortical margin of the tibia.



Images courtesy of Harcke, T., et al. (2011) Placement of Tibial Intraosseous Infusion Devices. *Military Medicine* (176)7:824

2. Axial and coronal images show incorrect placement of an intraosseous needle outside the intramedullary space of the proximal tibia.



Images courtesy of Harcke, T., et al. (2011) Placement of Tibial Intraosseous Infusion Devices. *Military Medicine* (176) 7:824

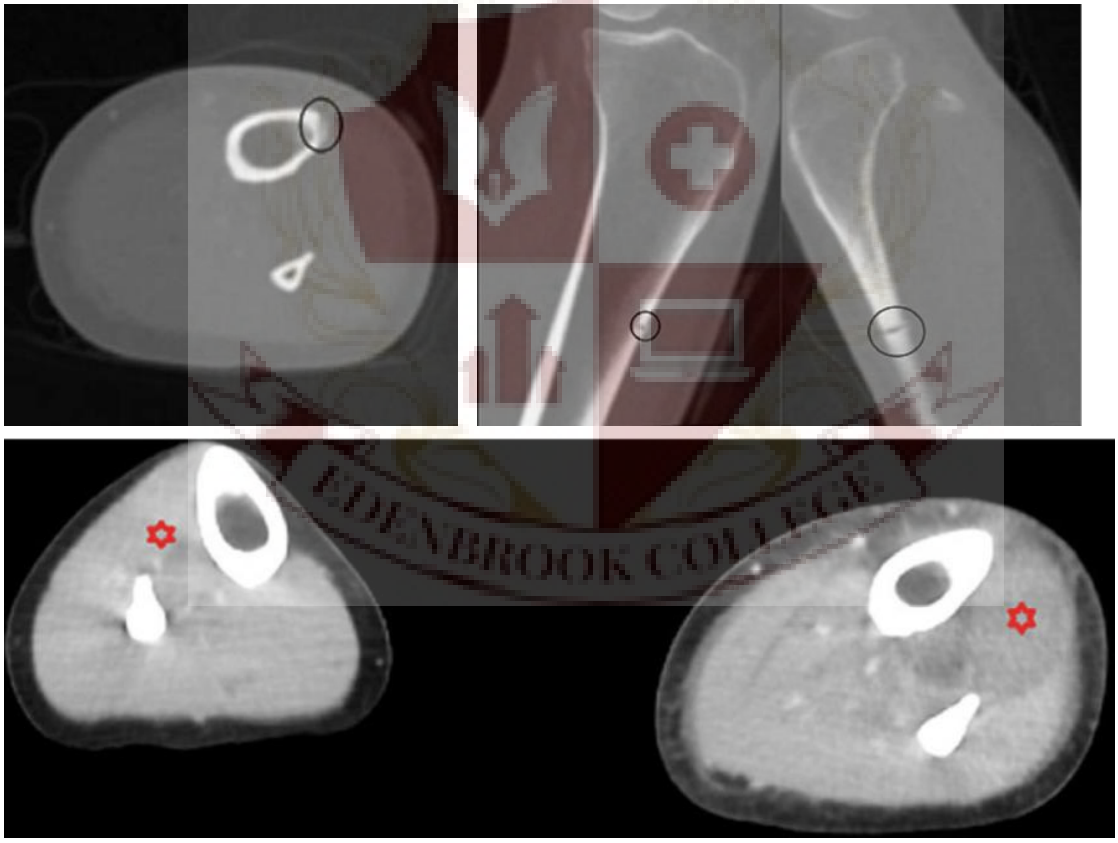
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Complications of Intraosseous Insertion

Staff need to be aware of the risks associated with IO contrast administration prior to, during and following the CT examination. Unintended outcomes include contrast media leakage from the infusion site causing extravasation. This may lead to compartment syndrome. Dislodgement of the IO needle may occur during high-pressure volume injections and or if the extremity is moved during patient transfer or positioning the patient in the CT scanner. Rare unintended complications from high-pressure volume injections include fat embolism and osteomyelitis as a result of IO insertion.

1. **Dislodgement**: there is a potential risk of IO needle dislodgement from movement when placed in the upper humerus. Dislodgement should be considered if the needle does not remain in an upright position without support. During transport, transfer from one surface to another, and during the CT examination, the patient's arm with the IO needle in should remain by their side.

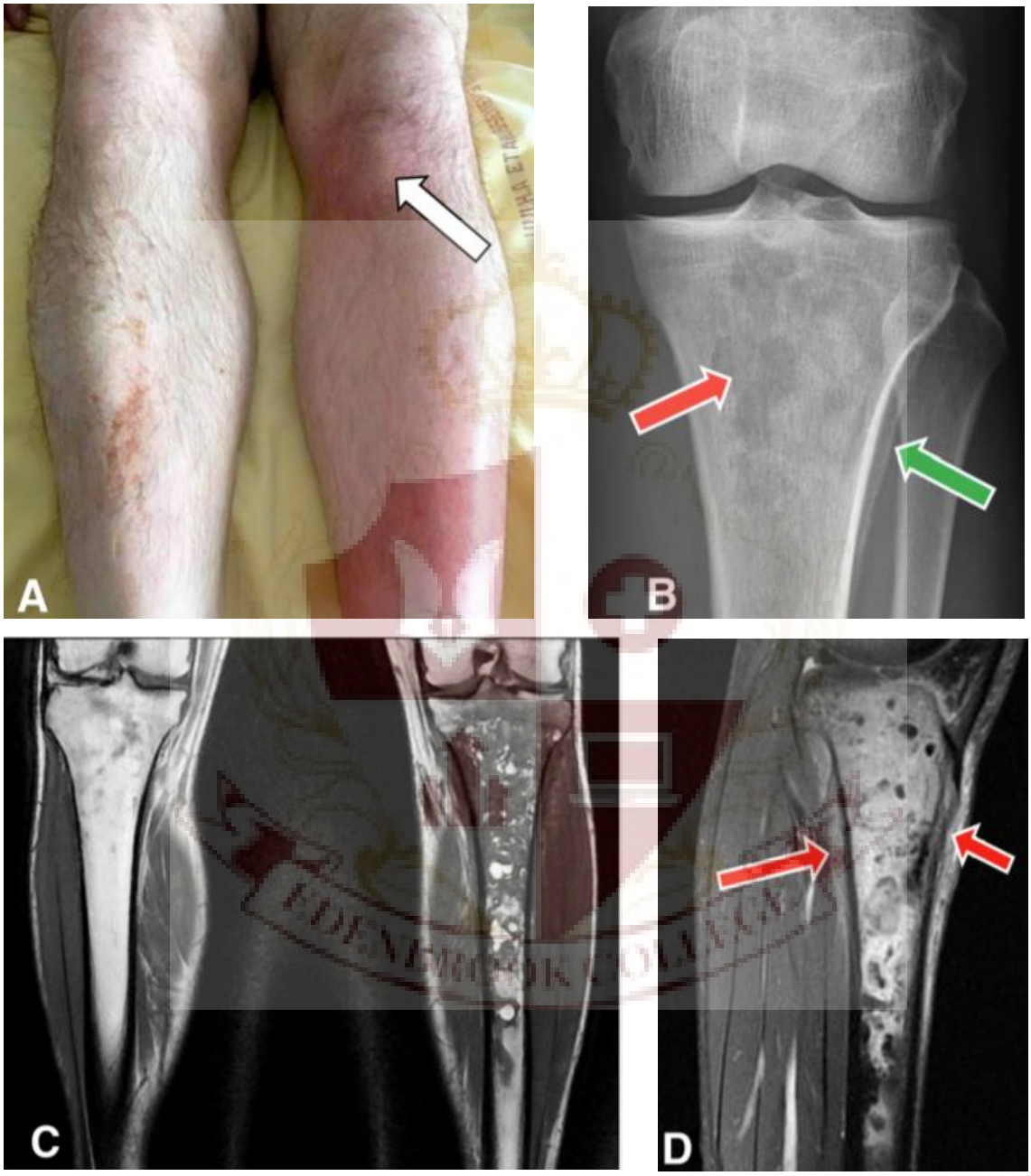
2. **Extravasation**: contrast extravasation can be a serious complication as a "result from incomplete penetration of the cortical bone, extension of the cannula through the proximal tibia into the posterior compartment of the leg, extravasation through previous IO puncture sites, and through nutrient vessel foramina." Extravasation can be a serious complication resulting in compartment syndrome and tissue necrosis. The radiologist should confirm the absence of fracture and correct IO needle placement and position prior to contrast administration.



Images courtesy of Wasserman, P. et al (2019) Intramuscular hemorrhage and fluid extravasation into the anterior compartment secondary to intraosseous resuscitation, the "Nicked-Cortex" sign.

(A) Axial, coronal, and sagittal CT planes demonstrates the lucent linear cortical defect (black circles) in 3 dimensions "CT Nicked-Cortex Sign." No intramedullary extension of the defect noted as would be expected with successful intraosseous access. (B) Axial CT comparison of the right and left lower extremities demonstrate an asymmetrically enlarged, low density left tibialis anterior muscle compared to the contralateral lower extremity, (red asterisks) suggesting increased compartmental pressure due to excess intramuscular fluid on the left.

3. **Emboli**: Fat and bone marrow emboli have been found in the lungs during autopsy. It is not known if this finding is correlative or caused during IO needle insertion or subsequent use.
4. **Osteomyelitis**: is a rare serious infection of the bone that can be caused by introducing bacteria during the IO needle insertion process or acquired through blood infection. See images below.



Images courtesy of Chapolin et al, (2018) *BMC Infectious diseases*.

A. Image of the left tibia, well-defined area with redness, warmth and swelling over his left proximal tibia corresponding to the site of the intraosseous injection (arrow). The contralateral leg is normal. **B.** X-rays of left proximal tibia in front view with multiple ill-defined lytic lesion in the metaphysis and the epiphysis and geographic pattern (red arrow) and also proximal tibial blurred periosteal appositions (green arrow). **C.** Coronal T1-weighted section with massive epiphyso-metaphyseal hypoT1 intra-medullary bone edema extended to the diaphysis up to the middle third of the leg. **D.** Sagittal fat-sat T2–weighted section with significant hyperT2 infiltration of soft tissues (arrows).

Contrast Administration: Intraosseous Route – Staff Education

Documentation

Record of Intraosseous Injections

All CT departments will need to print copy of the Record of Intraosseous Injections and have it accessible for MRT's to complete. MRT's will need to record injection data as a means to track and audit intraosseous contrast media administration. A Record of Intraosseous Injections of Contrast Media in CT form can be found in the Appendix section of these instructions. The information below is intended to facilitate completion the injection record.

Exam Data

i. **Accession # / Encounter #** -
ii. **Date of Exam** – write the date of the exam using the format dd-mmm-yyyy
iii. **Exam Description Mnemonics**
   a. **CTA - AP** = CT Angiogram – Abdomen/Pelvis (GI bleed, ischemic bowel, abdominal aorta)
   b. **CTA - C** = Coronary CT Angiogram
   c. **CTA - T** = CT Angiogram - Thoracic (Aortic dissection)
   d. **CTA - P** = CT Pulmonary Angiogram (Pulmonary embolus)
   e. **AP** = CT for Abdominal / Pelvis
   f. **Runoff** = Bi-femoral Angiogram
   g. **Stroke/Hot Stroke** = Stroke
   h. **WBCT**= Whole Body CT

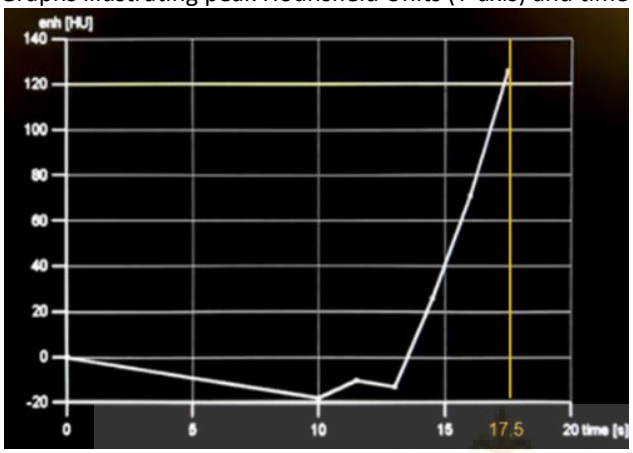
Contrast Administration Data

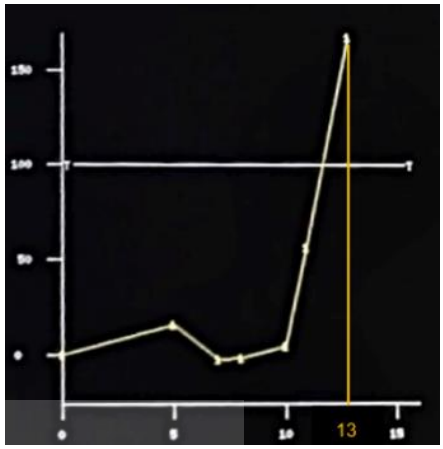
i. **Contrast** - include the type and contrast concentration. For example: Omni 300, Omni 350, Visipaque 320, Optiray 370.
ii. **Flow Rate** – document the rate in mLs/second the contrast was injected at. This information can be found on the injector module as well as the secondary capture image (below) sent to PACS. Maximum contrast flow rate is not to exceed 4.0 mLs/second.

Programmed		ml/s	ml	Actual		ml/s	ml
1	A	2.50	87.0	1	A	2.47	87.1
2	B	2.50	50.0	2	B	2.47	49.9

iii. **Injection Volumes** - document the volumes in millilitres (mLs) of both contrast media and Normal Saline 0.9% NaCl. If multiple injections were completed, document the total volume of each infusate administered. This information can be found on the injector
iv. **Intraosseous Needle Site and Side** – the two preferred sites for IO contrast administration are the proximal humerus and the proximal tibia. Indicate the site and side by using the following identifiers.
   a. **RH** – right humerus
   b. **LH** – left humerus
   c. **RT** – right tibia
   d. **LT** – left tibia
v. **Peak Contrast (HU)** – this value is taken from the graph during the monitor phase of arterial and bolus tracking measured in Hounsfield Units (HU).
vi. **Time to Peak** – from the graph on the injector document the time (in seconds) to reach the peak contrast. On the graphs below, the time to peak is indicated by the vertical orange lines. On the left graph, time to peak is 17.5 and on the right graph 13 seconds.

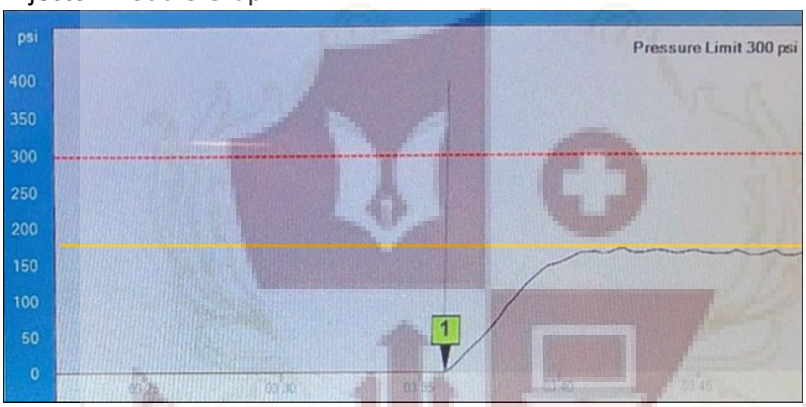
Graphs illustrating peak Hounsfield Units (Y-axis) and time in seconds on the X-axis.



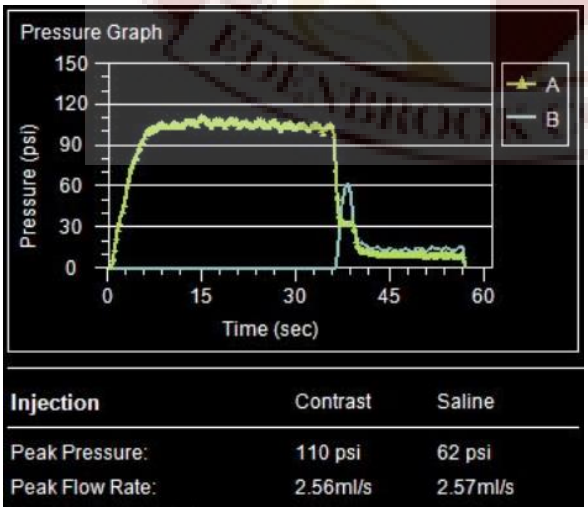


vii. **Injection Pressure (PSI)** – from the injector or the secondary capture sent to PACS, document the maximum pressure of the injection via the IO needle, indicated on the graph by the horizontal orange line.

Injector Module Graph



Secondary capture sent to PACS



Injection	Contrast	Saline
Peak Pressure:	110 psi	62 psi
Peak Flow Rate:	2.56ml/s	2.57ml/s

Contrast Administration: Intraosseous Route – Staff Education

Scan Acquisition Parameters

i. **kVp** - document the kVp used for the CT Examination. If dual energy was used, you will need to document both kVp values.

ii. **mAs** (**effective**) – for CT examinations that use a fixed mA, include that in the mA tab for the patient. If mA dose modulation was activated then enter the minimum and maximum values (100 – 350) in the range of mA.

iii. **$CTDI_{vol}$** – CT Dose Index $_{(volume)}$ is a calculation based on the $CTDI_w$ and accounts for pitch value (z-axis) used during a single acquisition. When tube current modulation is used, $CTDI_{vol}$ is based on the average mA used throughout the CT scan. For multiple phase and or multiple body part CT examinations you will need to enter more than one value. For combined studies of body parts (ie. neck, chest, abdomen and pelvis) and a single CTDI can be recorded.

iv. **DLP** – Dose Length Product is a measure of the CT tube radiation output/exposure over the entire length of the z-axis of the CT examination. For multiple phase and or multiple body part CT examinations you will need to enter more than one value. For combined studies of body parts (ie. neck, chest, abdomen and pelvis) and a single CTDI can be recorded.

IO Injection Success

i. **Yes** – if the patient tolerated the injection well and there was no complications

ii. **No** – if there was an adverse event as a result of the contrast media or saline injection put a check in the "no" box. Adverse events would include the needle dislodging, contrast extravasation or the contrast enhancement was not sufficient to evaluate the clinical scenario. All adverse events should be entered in PSLS.

   a. **Dislodgement**: select "**DH"** if the IO needle becomes separated from the IO infusion site.

   b. **Extravasation:** select "**EX"** if the saline and or contrast media collects underneath the skin. Often a lump will form at and or around the injection site when extravasation occurs.

   c. **Insufficient enhancement**: select "**IE"** if there were no other complications and the contrast enhancement of the vessels or organ did not answer the clinical question.

   d. **Other:** select "**O"** and add a comment as to why the IO injection was not successful.

Contrast Administration: Intraosseous Route – Staff Education

Record of Intraosseous Injections of Contrast Media in CT

Exam Data			Contrast Administration Data								Scan Acquisition Parameters				IO Injection Success		
Encounter # or Accession #	Date	*Exam Description	Contrast Type	Flow Rate	Injection Volume		IO Needle Side/Site	Peak Contrast	Time to Peak	Injection Pressure	kVp	mAs effective	CTDI vol	DLP	Yes	No	Adverse Event
	dd-mmm-yy	See legend below	Make / Contrast Concentration	Max. 4 mLs/sec	Contrast (mLs)	Saline (mLs)	**RH** = Right Humerus **LH** = Left Humerus **RT** = Right Tibia **LT** = Left Tibia	HU	Time in Seconds	Max. 300 PSI	If DE, include both		mGy	mGy/cm		**DL** = **Dislodge** **EX** = **Extravasation** **IE** = **Insufficient Enhancement** **O** = **Other** (describe)	
0123456789	**05-Mar-19**	**CTPA**	**Visi 320**	**4.0**	**60**	**40**	**RH**	**250**	**7**	**90**	**120**	**250**	**14**	**200**		✓	**IE**
1234567890	**11-Jul-19**	**WBCT**	**Omni 350**	**3.0**	**120**	**40**	**LT**	**200**	**9**	**100**	**80/140**	**450**	**25**	**600**	✓		

*** Exam Description** **CTA-AP =** CT Abdominal Angiogram (GI bleed, ischemic bowel, abdominal aorta) **AP** = CT Abdomen-Pelvis **CTA - C =** Coronary CT Angiogram **Runoff =** CT Bi-femoral Angiogram **CTA - P** = CT Pulmonary Angiogram **Stroke =** Stroke/Hot Stroke **CTA-T** = CT Angiogram Thorax (aortic dissection); **WBCT =** Whole Body CT

Contrast Administration: Intraosseous Route – Staff Education

IO Contrast Administration Checklist – Humerus and Tibia

- ☐ Radiologist communicates to MRT contrast dose and administration rate to a maximum 300 PSI at 4.0 mLs/second
- ↓
- ☐ MRT performs a scanogram/scout of limb with the IO needle. Radiologist to assess image(s) for fracture.
- ↓
- ☐ MRT completes a limited unenhanced CT scan of IO needle site for radiologist review prior to contrast injection.
- ↓
- ☐ Radiologist communicates to the clinical team the radiographic placement and position of the IO within the intramedullary space.
- ↓
- ☐ For conscious patients alert and responsive to pain stimuli, radiologist should confirm with the clinical team if IO anesthetic has been administered prior to contrast administration. If needed, radiologist to contact clinical team.
- ↓
- ☐ Clinical Team to follow institutional IO anesthetic administration protocol prior to contrast injection.
- ↓
- ☐ MRT connects new power compatible pressure rated CT extension set with two (2) back check valves to power injector and ensures it is primed and ready for use. (Follow LMMI Multi-Dosing Clinical Practice Standard)
- ↓
- ☐ Clinical Team to disconnect **non-power compatible** extension set from IO needle system
- ↓
- ☐ Clinical Team to connect **power compatible** CT extension set supplied by Medical Imaging directly to the IO needle
- ↓
- ☐ MRT injects 20-30 mLs pre-contrast NS 0.9% flush to assess if IO can accept prescribed injection parameters.
- ↓
- ☐ MRT performs contrast administration and diagnostic CT examination as per radiologist instructions.
- ↓
- ☐ Clinical Team disconnects power compatible CT extension set from IO needle.
- ↓
- ☐ MRT documents injection parameters in patient health record / contrast questionnaire.
- ↓
- ☐ MRT communicates any adverse events to contrast administration to clinical team and the radiologist.
- ↓
- ☐ MRT to document all adverse events related to contrast administration in patient health record and the ADR tab of PSLS

Contrast Administration: Intraosseous Route – Staff Education

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Definitions

Intraosseous infusion site: Uses the intraosseous space as a large non collapsible vein for the administration of fluids, medicine and contrast media.

Intraosseous Needle Device: a large gauge metal needle inserted using a needle driver or drill into the non-collapsible medullary cavity of long bones. These devices are used to administer fluids, medications, and contrast media into the systemic circulation when peripheral or central venous access is unable to be established.

Power Injector: Mechanical device used to administer contrast media and normal saline at prescribed rates and doses for CT examinations.

Pressure Rated Tubing: Tubing that has been approved for use with power injectors and can withstand medium to high pressure.

Intramedullary Space: the central cavity of bone shafts where red bone marrow and or yellow bone marrow are stored.

Epiphysis: the rounded ends of bone that contributes to a joint.

Diaphysis: the main shaft of a long bone with a hard outer section of cortical bone and a central portion of cancellous bone and bone marrow.

Haversian Canals: are systems (osteons) of microscopic channels that run parallel to the long axis of the bone in hard, outer cortical bone and allow capillary blood vessels and nerves to pass.

Volkmann Canals: are located inside osteons and run perpendicular to the long axis of the bone, interconnecting Haversian canals with each other and the periosteum. These channels transmit blood vessels from the periosteum into the bone and provide energy and nourishment to the osteons.

Osteon: main structural component of compact cortical bone, made up of layers of lamellae

Lacunae: a hollowed space within a bone

Lamellae: concentric layers of collagen fiber and cementing material that form a vascular canal, a part of the osteon.

Infusate: a fluid given intravenously over a period of time for medication or diagnostic purposes

Contrast Administration: Intraosseous Route – Staff Education

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