Basic Arterial Anatomy and Interpretation of Computed Tomography Angiography for Intraabdominal or Gastrointestinal Bleedings: Correlation with Conventional Angiographic Findings for Beginners

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Purpose
Introduction
Basic arterial anatomy
Angiographic findings of active bleeding
Case review with CT & conventional angiography
  • GI bleeding cases
  • Intraabdominal bleeding cases
Conclusions
This exhibition shows the basic arterial anatomy for beginners.

It will help to better understand and correlate computed tomography (CT) and conventional angiography images of active bleeding at GI tract and abdominopelvic cavity.
Introduction

- Contrast-enhanced CT & CT angiography
  - crucial for initial diagnosis in the evaluation of active bleeding

- Detection of active bleeding on CT
  → enable the immediate angiographic embolization

- The area of contrast leakage on CT
  - well-correlated with bleeding focus seen on angiography
  → helps to perform the embolization easier
Basic anatomy

Abdominal aorta

- Celiac trunk
- Superior mesenteric artery
- Right & Left renal arteries
- Inferior mesenteric artery

Right & Left common iliac arteries

* Other abdominal aorta branches are not in this diagram.
Basic anatomy

Pelvic cavity

Aorta

L4 level

Right & Left common iliac artery

Pelvic brim level (anterior to the SI joint)

External iliac artery

Inferior epigastric artery

Deep circumflex iliac artery

Inguinal ligament

Common femoral artery

Superficial femoral artery

Deep femoral artery

Internal iliac artery

Anterior division

Posterior division
1. Aorta
2. Celiac trunk
3. SMA & IMA
4. Renal a.
5. Iliac a.

*Typical anatomy will be reviewed, not considering of variation in origin and course*
1. Aorta
2. Celiac trunk
3. SMA & IMA
4. Renal a.
5. Iliac a.
**Basic anatomy**

- Continuation of descending thoracic aorta
- At the level of the diaphragm, via the aortic hiatus
- Important visceral branches

### Abdominal aorta

- Celiac trunk
- Superior mesenteric artery (SMA)
- Right & Left renal arteries
Basic anatomy

Abdominal aorta

- Continuation of descending thoracic aorta
- At the level of the diaphragm, via the aortic hiatus
- Important visceral branches

Inferior mesenteric artery (IMA)  Bifurcation to common iliac arteries

L3  L4-5
Basic anatomy

1. Aorta
2. Celiac trunk
3. SMA & IMA
4. Renal a.
5. Iliac a.
Basic anatomy

Celiac trunk

Common hepatic artery (CHA)
- Right gastric (RGA)
- Proper hepatic
  - Right hepatic & left hepatic (RHA, LHA)
  - Cystic artery
- Gastroduodenal (GDA)
  - Supraduodenal (SDA)
  - Right gastroepiploic (RGEA)
  - Anterior pancreaticoduodenal arcade
  - Posterior pancreaticoduodenal arcade

Left gastric artery (LGA)

Splenic artery
Basic anatomy

Celiac trunk

Three branches of celiac trunk

1. Common hepatic artery (CHA)
   - Right gastric artery (RGA)
   - Proper hepatic artery (PHA)
   - Gastroduodenal artery (GDA)
     - Supraduodenal artery (SDA)
     - Right gastroepiploic artery (RGEA)
     - Superior pancreaticoduodenal artery (SPDA)
       - Anterior pancreaticoduodenal arcade
       - Posterior pancreaticoduodenal arcade

2. Left gastric artery (LGA)

3. Splenic artery
   - Left gastroepiploic artery (LGEA)
   - Short gastric artery
   - Pancreatic branches
Basic anatomy

- Blood supply of stomach
Blood supply of stomach

- Right gastric artery
- Left gastric artery
  - run along lesser curvature & anastomosis each other
- Short gastric artery
- Right gastroepiploic artery
- Left gastroepiploic artery
  - run along greater curvature & anastomosis each other
Basic anatomy

- **Cystic artery** – arises from RHA (m/c), supply the gallbladder

- **Falciform ligament artery** - arises from LHA or MHA, runs within falciform ligament and reaches the umbilical area

Post-embolization complication
Basic anatomy

1. Aorta
2. Celiac trunk
3. SMA & IMA
4. Renal a.
5. Iliac a.
Superior mesenteric artery

- Arises less than 1~2cm below the celiac origin at **L1 level**
- Blood supply: **part of the duodenum ~ splenic flexure of colon**
- 1<sup>st</sup> branch: IPDA or middle colic artery or common branch of both

- Inferior pancreaticoduodenal artery (IPDA)- duodenum
  - Left-sided: **jejunal branches**- jejunum
    - ileal branches- ileum
  - Right-sided: **right colic artery** (RCA)- ascending colon
    - **middle colic artery** (MCA)- transverse colon
    - **ileocolic artery**- terminal ileum & cecum
Basic anatomy

- Superior mesenteric artery and branches

* IPDA arises more proximally → not visible on this illustration
Basic anatomy

- Superior mesenteric artery angiogram

- SMA & IMA

- IPDA
- Left-sided
  - Jejunal branches
  - Ileal branches

- Right-sided
  - Middle colic artery
  - Right colic artery
  - Ileocolic artery
Inferior mesenteric artery
- 3rd main branch of abdominal aorta (1st: SMA, 2nd: Renal a.)
- Arises approximately 7cm below SMA origin, L3 level
- All of branches arise from the left side
- Blood supply: splenic flexure ~ upper part of the rectum

Left colic artery: 1st branch
- ascending branch
- descending branch

Sigmoid arteries

Superior rectal artery: terminal branch

※ Notes: Middle, inferior rectal arteries
- from anterior division branches of internal iliac artery
Inferior mesenteric artery angiogram

- SMA & IMA

- Left colic artery
- Sigmoid arteries
- Superior rectal artery

* Marginal artery of the colon = Marginal artery of Drummond
  - arterial arcade that connects the SMA and IMA along the inner border of colon
Basic anatomy

- SMA collaterals
  - Marginal artery of Drummond
  - Arc of Bühler
  - Arc of Riolan

→ Important connection
  in SMA occlusion/significant stenosis, and vice versa
Basic anatomy

- SMA and collaterals
  * Marginal artery of Drummond
    - SMA & IMA

IMA angiogram

Basic anatomy

- SMA and collaterals
  * Arc of Riolan
    - SMA & IMA

SMA & IMA

Aortogram

Arc of Riolan

SMA

IMA

Basic anatomy

- SMA and collaterals
  * Arc of Bühler
    - SMA & Celiac trunk

SMA & IMA

Celiac angiogram

SMA angiogram

Gastroduodenal artery

Celiac trunk

Arc of Bühler

SMA
Basic anatomy

1. Aorta
2. Celiac trunk
3. SMA & IMA
4. Renal a.
5. Iliac a.
Basic anatomy

Renal arteries

- Arise between L1 and L2 body levels, inferior to SMA origin
  - Course in slightly posterior direction due to position of kidneys

- Right main renal artery
  - Courses inferiorly
  - Passes posterior to the IVC

- Left main renal artery
  - Arises below right renal artery
  - Courses more horizontally

27/M, for kidney donor evaluation

MIP
Basic anatomy

Renal arteries

- Main renal artery
  - Anterior branch
  - Segmental artery (apical, upper, middle, and lower)
  - Lobar artery
  - Interlobar artery
  - Arcuate artery
  - Interlobular artery
  - Posterior branch
Basic anatomy

1. Aorta
2. Celiac trunk
3. SMA & IMA
4. Renal a.
5. Iliac a.
Basic anatomy

Iliac arteries

- Aorta
- Common iliac artery
- External iliac artery
  - branches into
    - inferior epigastric artery
    - deep circumflex iliac artery
  - passes inguinal ligament & continues as common femoral artery
- Internal iliac artery
Basic anatomy

Iliac arteries

- **Internal iliac artery**
  - branches into
    - **anterior division**
      - umbilical artery
      - superior vesical artery
      - obturator artery
      - vaginal artery
      - inferior vesical artery
      - uterine artery
      - middle rectal artery
      - internal pudendal artery
      - inferior gluteal artery
    - **posterior division**
      - iliolumbar artery
      - lateral sacral arteries
      - superior gluteal artery
<table>
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<th>Relevant arteries</th>
<th>Blood supply</th>
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<td>Left gastric artery From celiac trunk</td>
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<td>Stomach - lesser curvature</td>
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<td>Right gastroepiploic artery From GDA of CHA of celiac trunk</td>
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<td>Stomach - greater curvature</td>
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<td>Inferior pancreaticoduodenal artery From SMA</td>
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<td>Pancreas head &amp; duodenum</td>
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<td>Right colic artery (RCA) Middle colic artery (MCA) From SMA</td>
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<td>Colon - RCA: ascending - MCA: transverse - LCA: descending</td>
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<td>Superior rectal artery From IMA</td>
<td>Middle rectal artery Inferior rectal artery From anterior division of IIA</td>
</tr>
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<td></td>
<td>Rectum</td>
</tr>
</tbody>
</table>

* CHA: common hepatic artery, GDA: gastroduodenal artery, IIA: internal iliac artery
CT angiography
- Noninvasive modality that could replace conventional angiography as the initial diagnostic tool
- Typically detects active bleeding with a rate that exceeds 0.3–0.5 mL/min

Conventional angiography
- Invasive examination that can be used for accurate localization as well as treatment
- Bleeding rates as low as 0.5 mL/min can be detected
• Signs of arterial bleeding
  • Active extravasation of contrast material
    • linear, jetlike, swirled, ellipsoid, or pooled configuration
    • jet or focal area of hyperattenuation within hematoma that fades into an enlarged, enhanced hematoma on delayed images on CT scan
  • Pseudoaneurysm formation
  • Arteriovenous fistula formation
  • Abrupt luminal narrowing of artery
  • Loss of opacification of artery
Image findings

**Active bleedings**

- **Examples**
  - Active extravasation of contrast material
  - Pseudoaneurysm formation

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**Coronal CT MIP**

- Portal phase
- Delay phase

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**Active bleedings**

- Pseudoaneurysm formation

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**Coronal CT MIP**

- CHA
- Splenic artery
- Celiac trunk
- SMA
- GDA
Case review

- With CT & conventional angiography
  - GI bleeding cases
    1. Gastroduodenal artery
    2. SMA- jejunal branch
    3. Ileocolic artery
  - Intraabdominal bleeding cases
    4. Left hepatic artery
    5. Lumbar artery
    6. Inferior epigastric artery
    7. Deep circumflex iliac artery
    8. Iliolumbar artery
    9. Superior gluteal artery
    10. Internal pudendal artery

* The image listing order is from top to bottom by default. When the order goes from bottom to top, it is mentioned.
Gastrointestinal bleedings

80/F, ulcer of duodenal 2nd portion on endoscopy– Abdomen CT

*FIG 5 & 6: from bottom to top

FIG1. The GDA branches the superior pancreaticoduodenal artery (SPDA). (B)~(D) SPDA (orange in D) divides into two branches as it descends, anterior and posterior branch (orange in B & C). These then run around the pancreas head and duodenum.
80/F, ulcer of duodenal 2nd portion on endoscopy– Abdomen CT

FIG2. (E) CT shows the three branches of celiac trunk. (F) & (G) GDA is branched from common hepatic artery. (H) - (J) Proper hepatic artery branches into right and left hepatic arteries (skyblue). (H) In this case, right gastric artery (gray) is branched from the left hepatic artery, although not visible in these images.
Active bleeding (yellow) is observed in the proximal duodenum and the anterior and posterior branches of superior pancreaticoduodenal artery are observed. Although it is not clearly traceable, it is probable that the branch of GDA such as SPDA is the problem, because it supplies the blood around this area.
Gastrointestinal bleedings

80/F, ulcer of duodenal 2nd portion on endoscopy – Convention angiography

FIG4. In square box, active bleeding is observed from the small branch of GDA. The left angiogram (Superselection) shows that the contrast agent flows along the inner lumen of the duodenum during contrast injection, like CT.
FIG 5. In the precontrast image, the high attenuated lesion (about 81 HU) is observed in the jejunal loop. In the arterial phase, the more higher attenuated lesions are observed, and the extent gradually increases. In this situation, it can be thought that the blood vessel supplying jejunum is the problem.

*: 3rd portion of duodenum
Gastrointestinal bleedings

FIG6. The extravasation in the jejunal branch of SMA is visible, and when the superselection is performed, the segment supplied from this jejunal branch is well visible. The extravasation site is well correlated with CT images.

56/M, massive hematochezia, Hb 7.7 – Conventional angiography
FIG7. The images of arterial and portal phases show the active bleeding in the terminal ileal lumen. In terminal ileum, out-pouching sac (yellow arc) is detected and the bleeding focus (orange arrow) is thought within the out-pouching sac.
FIG8. Both SMA angiogram and IMA angiogram are performed. Pseudoaneurysm (orange arrow) was observed on SMA angiogram and is considered as the lesion correlated with the bleeding focus in CT. IMA angiogram show no specific findings.
FIG9. Pseudoaneurysm (orange arrow) is well observed when contrast medium is injected into the ileal branch of Ileocolic artery. The contour of the terminal ileum is well visualized.
Intraabdominal bleedsings

17/M, liver contusion due to motorcycle TA– Abdomen CT

FIG10. There is the active bleeding in liver segment 4A. There is no arterial phase.
FIG11. The celiac angiogram and hepatic artery angiogram show the active bleeding of hepatic artery.
17/M, liver contusion due to motorcycle TA– Conventional angiography

**Intraabdominal bleedings**

**Left hepatic artery**

**FIG12.** Selective angiography of the right hepatic artery (yellow arrow) and its branches (orange, and skyblue arrows) shows no active bleeding.
17/M, liver contusion due to motorcycle TA– Conventional angiography

**Intraabdominal bleedings**

**Left hepatic artery**

**Hepatic artery angiogram**

**LHA - Selective angiogram**

**FIG13.** Selective angiography of the left hepatic artery (yellow arrow) shows the active bleeding. The catheter was further advanced into the medial branch (pink arrow). The following angiogram shows this branch is the bleeding focus.
54/M, Spontaneous bleeding, history of hemophilia – Lower extremity angio CT

FIG14. (A) The paired lumbar arteries arise in the posterolateral direction of the aorta and (B)~(D) course posterolaterally along the vertebral body. (E) The left fourth lumbar artery (arrows) enters the hematoma.
FIG 15. The delayed postcontrast images shows the progressively increasing density in the hematoma, which means active bleeding.
Intraabdominal bleedings

54/M, Spontaneous bleeding, history of hemophilia – Conventional angiography

FIG16. The aortogram shows extravascular leakage (yellow) of contrast material from the left fourth lumbar artery (orange).
Inferior epigastric artery

Intraabdominal bleedings

42/M, after hard exercise – Abdomen CT

* Fig 14: from bottom to top

**FIG17. (A) & (B)** The inferior epigastric artery (arrows) arises from the medial portion of the distal EIA. (C)~(E) It passes obliquely upward and (F) enter the rectus sheath.
Inferior epigastric artery

42/M, after hard exercise – Abdomen CT

FIG18. Delayed postcontrast images shows the progressively increasing high density.
Inferior epigastric artery

42/M, after hard exercise – Conventional angiography

FIG19. External iliac arteriogram (left) and inferior epigastric arteriogram (right) shows extravascular leakage (orange square).
6. **Inferior epigastric artery**

- One of two branches of external iliac artery
- Supply the anterior abdominal wall

- Arise from medial wall of distal EIA, just superior to inguinal ligament
  - Ascends in oblique path
  - Punctures the transversalis fascia
  - Enter the rectus sheath

- Anastomoses with superior epigastric artery
Intraabdominal bleedings

Deep circumflex iliac artery

83/F, outcar TA – Abdomen CT

* Fig 17: from bottom to top

FIG20. (A) The Deep circumflex iliac artery (orange arrow) arises from the lateral portion of distal EIA. (B)–(E) It runs superiorly parallel to inguinal ligament towards the anterior superior iliac spine (ASIS) and (F) then pierces the transverse abdominis to lie between it and the internal oblique muscle. 

Arterial phase

A

B

C

D

E

F

AIIS

Internal oblique muscle

Transverse abdominis

ASIS
Although the vascular course is not precisely tracked, active bleeding (green arrow) near the ASIS is considered a possible cause of deep circumflex iliac artery (orange arrow) injury. The left buttock hematoma will be mentioned later.
Intraabdominal bleedings

Deep circumflex iliac artery

83/F, outcar TA – Conventional angiography

FIG22. Although the inguinal ligament is not visible, the direction of the deep circumflex iliac artery (orange arrow) toward ASIS is well observed. Unlike inferior epigastric artery, deep circumflex iliac artery originates from lateral side of EIA.
Intraabdominal bleedings

Deep circumflex iliac artery

- One of two branches of external iliac artery

- Arise from lateral wall of distal EIA, just superior to inguinal ligament,
  - Run superiorly parallel to inguinal ligament towards anterior superior iliac spine (ASIS)
  - Passes through the transversalis fascia to continue along the iliac crest.
  - Pierces the transverse abdominis to lie between it and the internal oblique muscle
47/F, Recurrent active bleeding – Abdomen CT

* Fig 20: from buttom to top

FIG23. (A)–(E) The iliolumbar artery courses upward and laterally anterior to the SI joint. It divides into a lumbar and an iliac branch just above the pelvic inlet and (C) behind the psoas major muscle (PM). In this CT, the lumbar branch is not visible.
FIG24. The lumbar branch of the iliolumbar artery, runs superolaterally towards the anterior part of the sacral ala and the lateral part of the L5 body. The iliac branch runs laterally anterior to the iliacus muscle (toward iliac fossa).
Intraabdominal bleedings

Superior gluteal artery

83/F, outcar TA – Abdomen CT

FIG25. (A)~(C) CT scan shows the superior gluteal artery (SGA, arrow) arising from the posterior division of IIA. (D)~(F) CT scan shows SGA exiting the pelvis through greater sciatic foramen, posterior to the ilium (I) and above piriformis muscle (P). (E)~(F) CT scan shows the superficial (*) & deep (arrowheads) branches. Superficial branch runs between gluteus maximus (G max) and gluteus medius (G med) muscles.
Intraabdominal bleedings

Superior gluteal artery

83/F, outcar TA – Abdomen CT

FIG26. Active bleeding of the left buttock area (arrowhead) was observed mainly in the gluteus maximus muscle. Active bleeding observed in the left ASIS (*) is a previously described deep circumflex iliac artery case (case 7).
FIG 27. Superior gluteal artery is a branch of the anterior division of IIA and pass the superior portion of greater sciatic foramen (GSF), above the piriformis muscle (Piriformis muscle separates the GSF into superior and inferior portions). Inferior gluteal artery is a branch of posterior division and pass the inferior portion of the GSF.
Intraabdominal bleedings

**Superior gluteal artery**

- The largest branch of IIA
- Exits from pelvis through greater sciatic foramen (GSF), above superior border of the piriformis muscle (P)
- After leaving the pelvis, divided into
  - Superficial branch
    - between the gluteus maximus and medius
  - Deep branch
    - between the gluteus medius and minimus
FIG28. The internal pudendal artery (orange arrow) exits the pelvis together with the inferior gluteal artery (yellow arrow) through the lower part of the greater sciatic foramen. It crosses behind the ischial spine (IS), reenters the pelvis through the lesser sciatic foramen and runs medial to the obturator internus muscle (OI).
Intraabdominal bleedings

Internal pudendal artery

52/M, outcar TA – Conventional angiography

- Branch of the anterior division of the IIA
- Supply to external genitalia

- Passes through GSF, inferior to piriformis
  - Curves around ischial spine (IS) & sacrospinous ligament (SSL; superior border of LSF)
  - Re-enter the pelvis through lesser sciatic foramen
Knowledge of the arterial anatomy is essential to understand the relationship between the extravasation site on CT and the damaged artery visualized on angiography.

Although arterial variations are not mentioned in this review, Variations in vascular origin and courses are fairly common. However, if you know the typical cases, it is easily recognizable even when there is variation. So, it is important to know the basics first.