Distinguishing acute from chronic aortic dissections using CT imaging features

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ORIGINAL PAPER

Distinguishing acute from chronic aortic dissections using CT imaging features

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Outline

- Study objective.
- Methods.
- Study population.
- Imaging features.
- Statistical analysis.
- Results.
- Discussion.
- Limitations.
- Conclusion.

Study objectives

- To assess and compare a variety of CT imaging features in AAD and CAD.

- To determine if some combination of imaging features was reliably predictive of the acute versus chronic nature of the disease in individual patients.
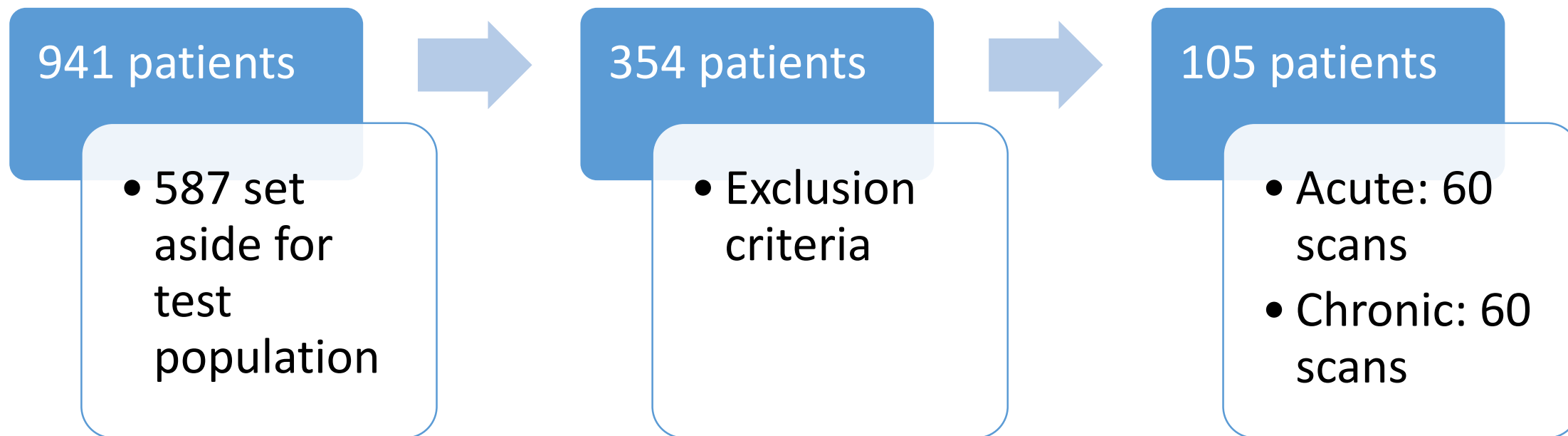
Methods

- **Study population.**
- **Imaging features evaluated.**
- **CT imaging techniques.**
- **Statistical analysis.**

Study population

- Retrospective study: 1/1/2010 - 1/1/2015.
- Patients seen at Cardiology and Cardiac Surgery clinic.
- Clinical diagnosis: Aortic dissection.
- Done CECT chest.
- Definition acute vs. chronic:
  - Acute   : < 2 weeks, closest scan to symptom onset.
  - Chronic   : > 2 months, most recent scan.
- Sorted in reverse chronological order.
- Divided into 2 groups:
  - Initial set of patient   : evaluate CT features, for predictive model.
  - Test population   : to test predictive model.

Exclusion criteria

- Undergone open aortic surgery.

- Endograft placement prior to the initial CT.

- Any of the following findings were present at CT:
  - focal dissection flap (<10 cm in length).
  - acute dissection superimposed on known chronic dissection.
  - very poor vascular opacification.

941 patients

- 587 set aside for test population

354 patients

- Exclusion criteria

105 patients

- Acute: 60 scans
- Chronic: 60 scans

Imaging features

- Done by a trained and supervised medical student.
  - 1st 10 CTs seen simultaneously with cardiothoracic radiologist.
  - Radiologist available throughout data collection.
  - Intra-observer variability – 10 CTs re-evaluated.
- 2 type of variables:
  - Categorical: 10 variables.
  - Continuous: 4 variables.

CT protocol

- Contrast + plain: 45/120 of initial group.

- Location:
  - Outside: 126/240.
  - At institution: 114/240.

- ECG-gating:
  - Non-ECG gated: 157/240.
  - ECG gated: 83/240.
    - Prospective ECG gated: 18/83.
    - Retrospective ECG gated: 65/83.

- Slice thickness: 0.5 – 5mm. (2 outside scans 7 – 7.5mm).

Categorical variables

- Present at least 1 on cross sectional image.
- Include:
  1. FL outer wall calcification.
  2. FL non-occlusive thrombus.
  3. FL regions of high attenuation (60-70 HU) – plain.
  4. FL-side flap calcification.
  5. Flap shape.
  6. Tear edges.
  7. Tear edge curl.
  8. Periaortic fat infiltration.
  9. Pericardial effusion.
  10. Pleural effusion.

Continuous variables

1. FL maximum diameter.
   - Largest luminal measurement perpendicular to the plane of the flap from the flap edge bordering the FL to the inner edge of the FL outer wall.
2. FL:TL area.
   - Ratio of the axial cross sectional area of the FL to the TL.
   - Four areas:
     I. Distal LSA.
     II. At celiac trunk.
     III. Halfway between LSA and celiac trunk.
     IV. Mid-asc.
3. Flap thickness:
   - The largest edge-to-edge measurement perpendicular to the plane of the flap.
4. Flap mobility:
   - Maximum amplitude of flap movement, measured perpendicular to the plane of the flap.
   - Retrospective ECG gating: same level in different cardiac phases.
   - Without ECG gating: maximum perpendicular distance between corresponding flap edges on consecutive axial sections.

Statistical analysis

- Categorical data : χ^2 test or Fischer's exact test.
- Continuous data : Two-sample t test or Wilcoxon rank sums test.
- Multiple logistic regression :   Firth's penalized maximum likelihood estimation.
    - Fitted into acute/chronic AD in first dataset.
    - Produce fitted model in odds ratio - predictors.
    - 5 predictors selected:
        I.   FL maximum Ø.
        II. FL thrombus.
        III. Visible tear edges.
        IV. Flap shape.
        V.   Flap motion.

Applied in test dataset to compute:
i.   Predicted probability, P.
ii. Sensitivity.
iii. Specificity.
iv. PPV.
v.   NPV.

Results

Table 1 Imaging features in acute and chronic aortic dissections

Variable	Acute (N=60 patients[a])	Chronic (N=60 patients[a])	P-value*
Flap thickness (mm)	2.90±0.87	4.01±1.15	<0.0001**S
FL maximum diameter (mm)	26.05±9.89	32.07±10.2	0.0005**S
FL/TL area ratio			
Mid ascending aorta	3.57±3.93 (N=26[b])	2.05±1.31 (N=5)	0.28**
Distal LSA	2.09±1.25 (N=55)	3.45±2.44 (N=45)	0.01**S
At celiac trunk	3.21±3.78 (N=51)	3.48±4.87 (N=50)	0.051**
Halfway between LSA and celiac trunk	2.61±1.88 (N=56)	3.93±2.12 (N=50)	0.0003**S
Pre-contrast scan available			0.09
Yes	18 (30%)	27 (45%)	
If yes, high attenuation in FL	3 (16.7%)	0	0.06**
No	42 (70%)	33 (55%)	
Pericardial effusion			0.51
Yes	6 (10%)	4 (6.7%)	
No	54 (90%)	56 (93.3%)	
Pleural effusion			0.75
Yes	5 (8.3%)	6 (10%)	
No	55 (91.7%)	54 (90%)	
FL-side flap calcification			0.36**
Yes	1 (1.7%)	4 (6.7%)	
No	59 (98.3%)	56 (93.3%)	
FL outer wall calcification			<0.0001**S
Yes	0	17 (28.3%)	
No	60 (100%)	43 (71.7%)	
FL thrombus			<0.0001S
Yes	6 (10%)	41 (68.3%)	
Indeterminate	21 (35%)	1 (1.7%)	
No	33 (55%)	18 (30%)	
Fat infiltration			0.0046**S
Soft tissue stranding	13 (21.7%)	5 (8.3%)	
Confluent soft tissue opacity	5 (8.3%)	0	
No	42 (70%)	55 (91.7%)	
Visible tear edges			<0.0001S
Yes	29 (48.3%)	53 (88.3%)	
If yes, tear edges curled into FL	6 (20.7%)	24 (45.3%)	0.03S
No	31 (51.7%)	7 (11.7%)	
Flap shape			<0.0001*S
Straight	4 (6.7%)	49 (81.7%)	
Curved	56 (93.3%)	11 (18.3%)	
Flap motion (mm)	6.62±4.94 (n=53)	1.69±1.84 (n=52)	<0.0001**S

[a]N=60 patients for all values unless otherwise indicated in the associated box

[b]One of the 27 acute type A dissections did not extend to the mid ascending aorta

*Two-sample t test for continuous variables and χ^2 test for categorical variables

**Wilcoxon rank sums test for continuous variables and Fisher's exact test for categorical variables

SSignificant at 5% level of significance

Continuous variables

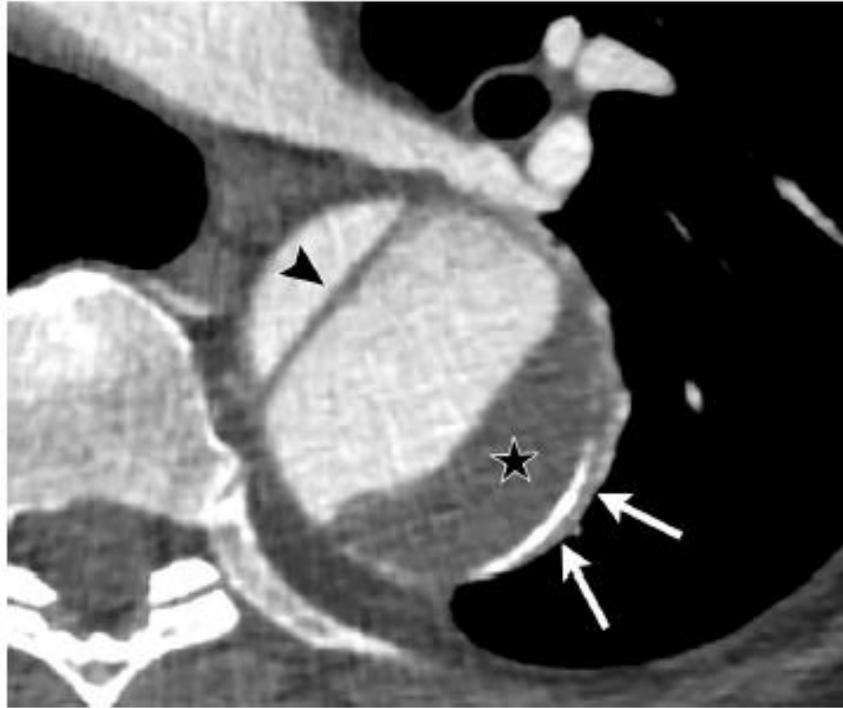| Variable	Acute (N = 60 patients[a])	Chronic (N = 60 patients[a])	P-value*
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FL/TL area ratio			
Mid ascending aorta	3.57 ± 3.93 (N = 26[b])	2.05 ± 1.31 (N = 5)	0.28**
Distal LSA	2.09 ± 1.25 (N = 55)	3.45 ± 2.44 (N = 45)	0.01**[S]
At celiac trunk	3.21 ± 3.78 (N = 51)	3.48 ± 4.87 (N = 50)	0.051**
Halfway between LSA and celiac trunk	2.61 ± 1.88 (N = 56)	3.93 ± 2.12 (N = 50)	0.0003**[S]
Flap motion (mm)	6.62 ± 4.94 (n = 53)	1.69 ± 1.84 (n = 52)	<0.0001**[S]

Flap motion
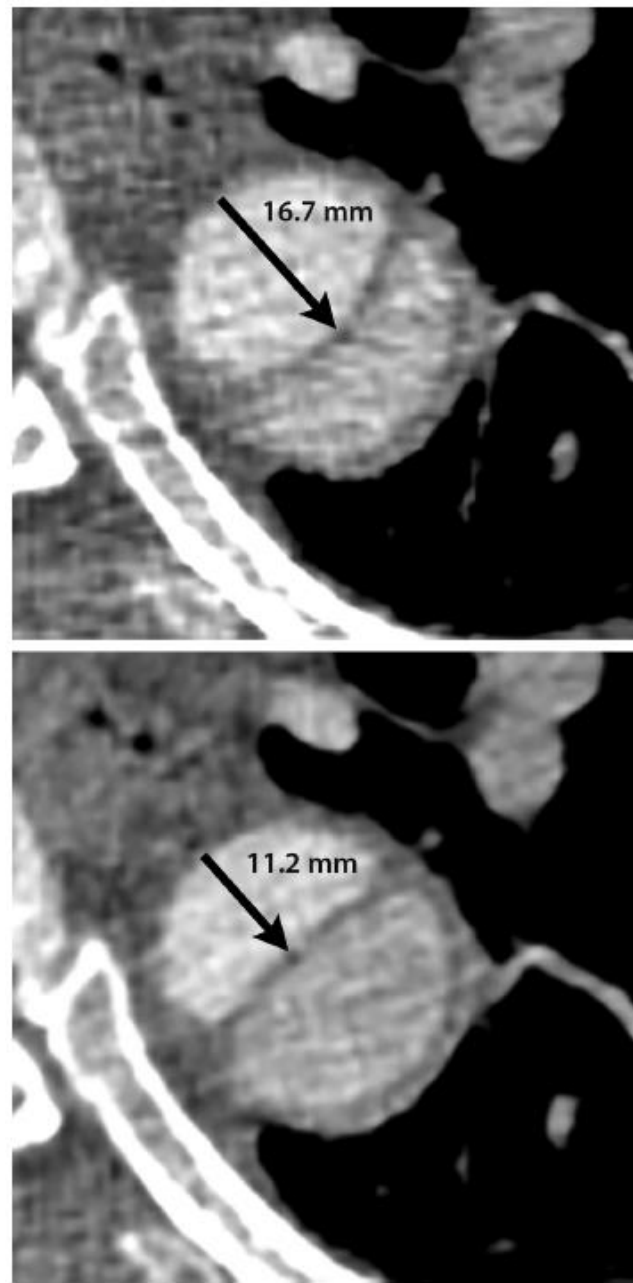
Fig. 6 A 45 year-old male with an acute type A dissection. Retrospectively-gated CT scan at the level of the proximal descending aorta demonstrates flap movement (arrows) of 5.5 mm in amplitude during different phases of the cardiac cycle

CATEGORICAL

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Flap shape			<0.0001*S
Straight	4 (6.7%)	49 (81.7%)	
Curved	56 (93.3%)	11 (18.3%)	

Fig. 2 61 year-old male with an approximately 11 year-old chronic type B aortic dissection. CT scan at the level of the proximal descending thoracic aorta shows a straight flap (arrowhead), FL thrombus (star), and FL outer wall calcification (arrows)
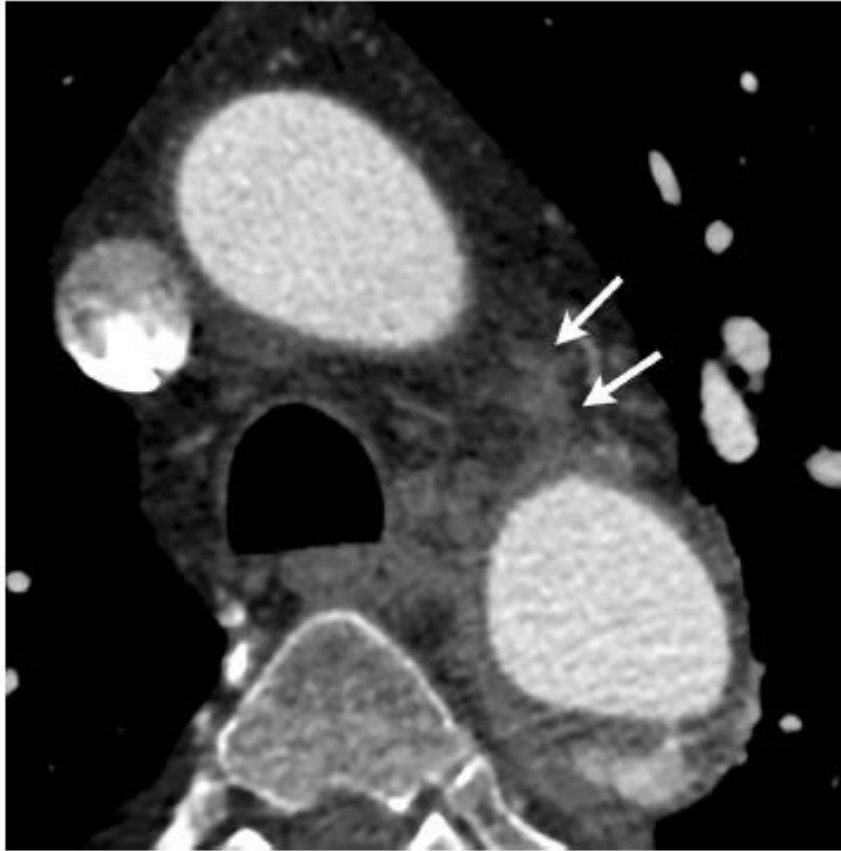
Fig. 3 57 year-old male with a chronic, 105 day-old type B aortic dissection. CT scan at level of aortic arch shows peri-aortic soft tissue stranding (arrows)
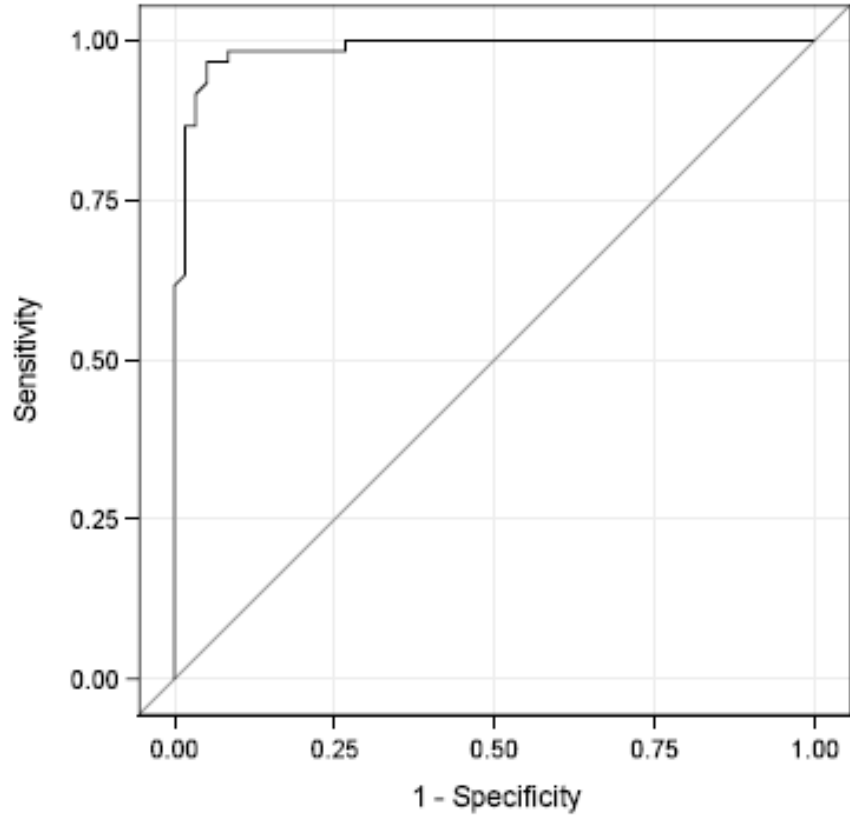

Fig. 4 68 year-old male with an acute type B aortic dissection. CT scan at the level of the aortic arch exhibits confluent soft tissue opacity (arrows)

Fig. 5 57 year-old male with a chronic, 100 day-old type B aortic dissection. CT scan near the level of the diaphragm shows a dissection flap tear edge (arrow) that is thickened and curled into the FL

Table 2 Odds ratios using multiple logistic regression analysis on the presence of a CAD adjusted for imaging features

Effect	Odds ratio (95%CI)	P-value
FL maximum diameter	1.140 (1.032, 1.301)	0.0140
➡ Visible tear edges	➡ 6.847 (1.345, 55.602)	0.0312
➡ Straight flap shape	➡ 22.501 (4.589, 200.968)	0.0004
Flap motion	0.774 (0.602, 0.936)	0.0162
➡ FL thrombus: present versus indeterminate/absent	➡ 7.967 (1.479, 58.544)	0.0199

Fig. 7 ROC curve for predicting the chronicity of an aortic dissection generated from the application of our predictive model to our test data set with 95% CI. The ROC curve yielded an area under the curve (AUC) of 0.98 (CI 0.98–1.00) with an associated sensitivity of 0.95 (58/61, CI 0.90–1.00), specificity of 0.97 (57/59, CI 0.92–1.00), PPV of 0.97 (58/60, CI 0.92–1.00), and NPV of 0.95 (57/60, CI 0.89–1.00)

- Sensitivity : 95%.
- Specificity : 97%.
- PPV : 97%.
- NPV : 95%

Fig. 8 Algorithm to determine the chronicity of a dissection. Key for variables in equation: D=FL maximum diameter (mm); V = 1 if tear edges visible, 0 if not visible; S = 1 if flap is straight, 0 if curved; M = flap motion (mm); T = 1 if FL thrombus present, 0 if absent or indeterminate. Asterisk does not exclude the possibility of a co-existing dissection

```
            Aortic dissection visualized on
                 CT scan with IV contrast

   FL outer wall calcification        Confluent soft tissue opacity

                No                              No

        Yes                                              Yes

   Chronic dissection present*          Acute dissection present*

        P= {log(1.140) x D} + {log(6.847) x V} +
           {log(22.501) x S} + {log(0.774) x M} +
                    {log (7.967) x T}

        where P > 0 corresponds to chronic
               and P < 0 to acute
```

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FL thrombus: present versus indeterminate/absent	7.967 (1.479, 58.544)	0.0199

Discussion

- Distinguishing acute vs chronic AD is vital → affect mx.
  - Surgical: acute Type A.
  - Medical: uncomplicated acute Type B or chronic.
- Atypical presentation – problematic - could be acute or previously undiagnosed chronic AD.

Chronic AD

- False lumen (FL):
    1. Outer wall calcification → only seen in chronic.
        - Long time needed for FL to endothelialize – calcify.
    2. Thrombus – stasis due to aneurysmal degen. + atheromatous neointima changes.
    3. Size:
        - Area ratio FL:TL – higher → aneurysmal degen.
            - Significant at: just distal to LSA & midpoint between LSA and celiac trunk (proximal desc. aorta).
   - Max. ∅ : FL greater in chronic.

- Flap.
  1. Thickens and shortens as it matures – elastic recoil, fibrosis and neointima formation.
  2. Shape: straight.
  3. Mobility: less mobile.
  4. Tear edge:
     - Due to above reasons.
     - Curls into FL – elastic recoil of elastin rich media layer + fibrosis.

Periaortic fat infiltration.

- Physiologic – soft tissue stranding (in both acute & chronic).
- Pathologic – confluent soft tissue opacity → mediastinal hematoma from leaking false lumen.
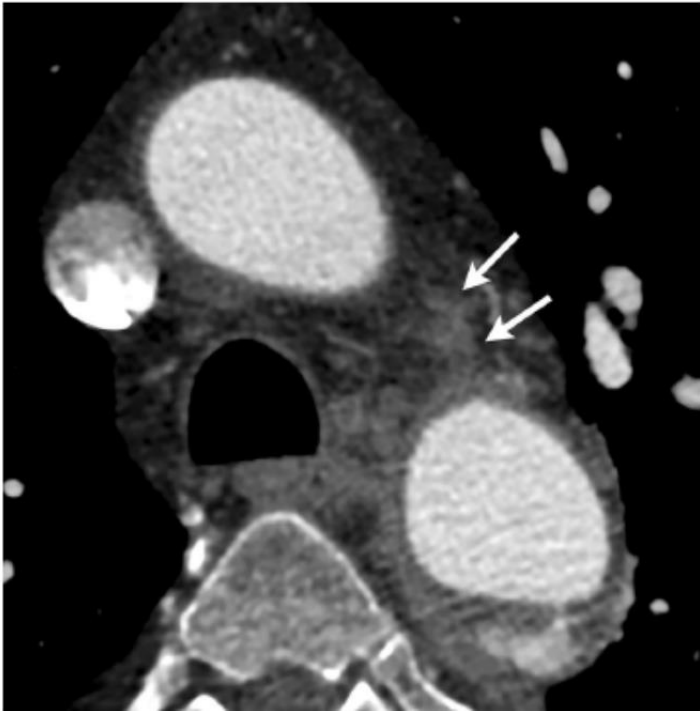
Limitations

- Heterogeneity:
  - Type A – small number → proceed with emergency surgery.
  - CT protocols → reflect real life situation.
- Age: test group older on average than initial group.
- Not evaluating subacute (2 weeks to 2 months).

Conclusion

- Acute and chronic aortic dissections showed significantly different CT imaging features.
- Acute dissections:
  - periaortic confluent soft tissue opacity.
  - curved dissection flap.
  - highly mobile dissection flap.
- Chronic dissections:
  - thick dissection flap.
  - FL outer wall calcification.
  - FL thrombus.
  - dilated FL.
  - visible tear edges curling into the FL.
- This information may supplement the treating clinician's judgment when confronted with an atypical clinical presentation.

THANK YOU