Straight to CT: Using Body Mass Index (BMI) to Guide First-Line Imaging Selection in Suspected Cases of Acute Appendicitis

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Background

- Appendicitis is the **most common surgical emergency** with an annual incidence of 96.5-100 cases per 100,000 adults. However, it's classic presentation (anorexia and periumbilical pain followed by nausea, right lower quadrant pain, and vomiting) occurs in only 50% of cases, significantly limiting the utility of just clinical history and physical examination. [1, 2]
- Current clinical guidelines recommend point-of-care or formal **ultrasonography (US) as first-line imaging**. However, the diagnostic information provided by an US significantly varies depending on patient presentation, appendix positioning, and technologist ability. [3, 4]
- Limited accuracy of US in certain cohorts – such as those with a higher Body Mass Index (BMI) – may delay care, increase cost, and ultimately increase morbidity [5-11].
- The current study explores the **relationship between various clinical characteristics and the diagnostic accuracy of US in suspected cases of acute appendicitis** to aid in selecting the most effective first-line imaging.

Methods

- Data was gathered via retrospective chart review of an integrated healthcare system (Hawaii Permanente Medical Group) with all medical encounters documented within a common electronic medical record
- We reviewed the results of all **adult subjects** (age ≥ 18 years) with abdominal pain who underwent an abdominal US during 2023
  - Our main analysis included all nongravid adults
  - A separate sub-analysis included all female patients (due to perfect collinearity sex and pregnancy status)
- Recorded variables included:
  - Ordering department (emergency department versus primary care)
  - Date of ultrasound examination
  - Age at the time of imaging
  - Sex (male/female)
  - Height, weight, and body mass index recorded closest to the examination date
  - Temperature and white blood cell count obtained nearest to imaging
  - Presence of nausea, vomiting, or anorexia
  - Presence of isolated right lower quadrant pain
  - Pregnancy status (if applicable)
  - Ultrasound findings
  - Final diagnosis of appendicitis
  - Any additional imaging performed within 30 days of the index ultrasound
  - Other relevant clinical data.
- US results were coded as either **concordant** if the US findings were **consistent with the final clinical/surgical diagnosis** or not concordant if they were not consistent or inconclusive
- Univariate and multivariable logistic regression analyses were conducted to evaluate predictors of US concordance

Results

Participant Characteristics

- Total adult subjects: n = 351
  - Concordant group: n = 108
  - Non-concordant group: n = 243
- Significant differences noted between groups in weight, BMI, pregnancy status, ordering department, and presence of isolated RLQ pain (see Table 1), but no significant difference in all other variables

Table 1: Descriptive Statistics and Comparative Analysis Between US Concordance Groups

Variables*	Concordant Group	Non-Concordant Group	p-value
Weight (kg)	64	68	0.003
BMI	23	25	<0.001
Pregnant	19%	33%	0.032
US ordered from the ED	53%	70%	0.003
Isolated RLQ pain	73%	56%	0.004

*Only variables with significant differences are reported in this table

Ultrasound Statistics & Diagnostic Accuracy

- Majority of US orders originated from the emergency department (n = 227, 64.7%)
- Only 120 subjects (34%) had a diagnostic US study
  - Remaining US studies were either inconclusive or appendix was not visualized
- Among all **nongravid adults**, in multivariable logistic regression, **US concordance** was significantly associated with…
  - **High BMI (≥25) inversely**: OR = 0.45, 95% CI: 0.24-0.83, p = 0.012
  - **Isolated RLQ pain directly**: OR = 2.21, 95% CI: 1.18-4.28, *p* = 0.015
  - All other predictors were not statistically significant
- The predicted probability of a concordant US decreased as BMI increased (Figure 1A)

Pregnancy

- Among all female patients, in multivariable logistic regression, US concordance was not significantly associated with any of the variables
- Although BMI was not a significant predictor, predicted probability of a concordant US decreased as BMI increased in this cohort as well (Figure 1B)

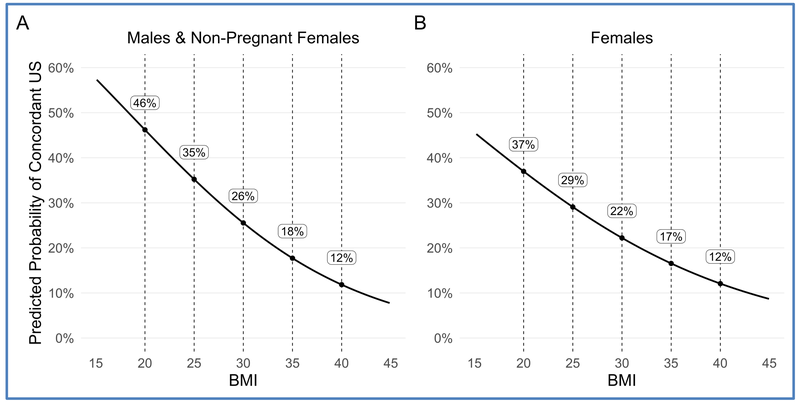

Figure 1. Predicted probabilities of concordant US findings across BMI values among (A) nongravid adults (males and non-pregnant females) and (B) all females.

Results (continued)

Additional Imaging

- 27% of patients received follow up CT imaging
- Among all nongravid adults, in multivariable logistic regression, follow up CT imaging was significantly associated with…
  - Elevated WBC count: OR = 1.97, 95% CI: 1.01-3.87, p = 0.047
  - Ordering department (from the ED): OR = 4.90, 95% CI: 2.31-11.2, p < 0.001
  - All other predictors were not statistically significant
- Other additional imaging options performed included MRI and pelvic or transvaginal US
  - MRI: 3 subjects (0.9%)
  - Pelvic or transvaginal US: 137 subjects (39%)

Discussion

- In our cohort of 351 adult subjects, only **34%** of subjects received an **US exam that was diagnostic** and not inconclusive
- Among **non-gravid adults**, **a high BMI (≥ 25)** was associated with a **55% reduction** in the odds of a **concordant ultrasound diagnosis** of appendicitis compared to those with a BMI < 25, whereas **isolated RLQ pain** was associated with **more than a twofold increase** in the odds of a concordant diagnosis
- While most US orders originated from the emergency department, over **one-third of requests for abdominal ultrasound** in our study were **generated from the outpatient primary care setting**, suggesting that more primary care providers are not only becoming more involved in the management of acute appendicitis but also in its diagnosis
- A nondiagnostic ultrasound can delay treatment and add to the cost of care; thus, considering the significantly decreased odds of an accurate US among overweight patients with suspected appendicitis, clinicians should consider sending nongravid patients with a BMI ≥ 25 directly to CT, especially if they do not have isolated RLQ pain

References

1. Moris D, Paulson EK, Pappas TN. Diagnosis and Management of Acute Appendicitis in Adults: A Review. JAMA. 2021 Dec 14;326(22):2299-2311. https://doi.org/10.1001/jama.2021.20502.
2. Yeh B. Evidence-based emergency medicine/rational clinical examination abstract. Does this adult patient have appendicitis? Ann Emerg Med. 2008 Sep;52(3):301-3. https://doi.org/10.1016/j.annemergmed.2007.10.023.
3. Snyder MJ, Guthrie M, Cagle S. Acute Appendicitis: Efficient Diagnosis and Management. Am Fam Physician. 2018 Jul 1;98(1):25-33.
4. Karul M, Berliner C, Keller S, Tsui TY, Yamamura J. Imaging of appendicitis in adults. Rofo. 2014 Jun;186(6):551-8. https://doi.org/10.1055/s-0034-1366074.
5. Josephson T, Styrud J, Eriksson S. Ultrasonography in acute appendicitis. Body mass index as selection factor for US examination. Acta Radiol. 2000 Sep;41(5):486-8. https://doi.org/10.1080/028418500127345749.
6. Pelin M, Paquette B, Revel L, Landecy M, Bouveresse S, Delabrousse E. Acute appendicitis: Factors associated with inconclusive ultrasound study and the need for additional computed tomography. Diagn Interv Imaging. 2018 Dec;99(12):809-814. https://doi.org/10.1016/j.diii.2018.07.004.
7. Sauvain MO, Tschirky S, Patak MA, Clavien PA, Hahnloser D, Muller MK. Acute appendicitis in overweight patients: the role of preoperative imaging. Patient Saf Surg. 2016 May 17;10:13. https://doi.org/10.1186/s13037-016-0102-0.
8. Pfeifer CM, Xie L, Atem FD, Mathew MS, Schiess DM, Messiah SE. Body mass index as a predictor of sonographic visualization of the pediatric appendix. Pediatr Radiol. 2022 Jan;52(1):42-49. https://doi.org/10.1007/s00247-021-05176-8.
9. Keller C, Wang NE, Imler DL, Vasanawala SS, Bruzoni M, Quinn JV. Predictors of Nondiagnostic Ultrasound for Appendicitis. J Emerg Med. 2017 Mar;52(3):318-323. https://doi.org/10.1016/j.jemermed.2016.07.101.
10. Yiğiter M, Kantarci M, Yalçin O, Yalçin A, Salman AB. Does obesity limit the sonographic diagnosis of appendicitis in children? J Clin Ultrasound. 2011 May;39(4):187-90. https://doi.org/10.1002/jcu.20782.
11. Lam SH, Kerwin C, Konicki PJ, Goodwine D, Lambert MJ. Body Mass Index is a Poor Predictor of Bedside Appendix Ultrasound Success or Accuracy. West J Emerg Med. 2016 Jul;17(4):454-9. https://doi.org/10.5811/westjem.2016.5.29681.