REVIEW ARTICLE

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Acute Abdomen in the Modern Era

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Acute abdominal pain is one of the most common symptoms in patients presenting to the emergency department and accounts for 5 to 10% of all emergency department visits.[1-4] Pathophysiological conditions that lead to surgical interventions in such patients are mainly gastrointestinal obstruction, hemorrhage, ischemia, and viscus perforation.[5] Acute abdominal pain can be diffuse or localized (i.e., quadrant-based epigastric pain or pain in the right upper quadrant, left upper quadrant, right lower quadrant, or left lower quadrant)[2,4,6] and is associated with but not limited to the following disease processes: perforated viscus, peptic ulcer disease, mesenteric ischemia, acute cholecystitis, appendicitis, diverticulitis, pancreatitis, and intraabdominal hemorrhage.[4] The need for emergency general surgery is an independent risk factor for postoperative complications and death, indicating the severity of the condition.[7] Therefore, timely diagnosis of acute abdominal emergencies is essential. From antiquity to modern times, medical students have been taught that the history and the physical examination are the central components in the evaluation of acute abdominal pain.[5]

In 1921, Vincent Zachary Cope, an English physician, surgeon, author, historian, and poet, wrote the seminal treatise, *Early Diagnosis of the Acute Abdomen*.[8] He was concerned that too many patients suffered from an inordinate delay in the clinical diagnosis and treatment of acute abdominal pain, resulting in poor clinical outcomes. On the basis of his personal experience and observation, Cope believed that a thorough history taking and physical examination of the patient, with a grouping of symptoms and signs, would lead to an accurate diagnosis and an expeditious (often surgical) intervention. Cope wrote *Early Diagnosis of the Acute Abdomen* without the benefit of advanced imaging studies. He would later receive a knighthood for his work on medicine and surgery in the official British medical history of the Second World War.

Today, the primary care physician, emergency department physician, or advanced practice provider (nurse practitioner or physician assistant) is often the first clinician to evaluate a patient with acute abdominal pain. These nonsurgical clinicians may administer analgesic agents and order laboratory tests and diagnostic imaging. Concurrently with or after diagnostic testing, they decide when to request surgical consultation. Cognitive biases can delay surgical intervention, and the delay may lead to poor outcomes. Despite the advent of advanced imaging techniques (e.g., ultrasonography, computed tomography [CT], and magnetic resonance imaging [MRI]), diagnostic errors and delays in surgical intervention for abdominal emergencies persist.

How would Cope's 1921 paradigm, anchored on the history and physical examination, apply today, given the availability of diagnostic imaging and our susceptibility to cognitive bias? In this selective review, we explore, first, the effect of administering an analgesic agent during the initial evaluation of acute abdominal pain; second, the essential role of imaging, particularly in older adults; third, the

importance of timely surgical consultation; and finally, cognitive biases that can lead to false conclusions and incorrect diagnoses. In addressing these factors, several questions naturally emerge. How do we integrate clinical suspicion with the ready availability of diagnostic imaging? How do findings on diagnostic imaging drive decision making, given clinical suspicion? How do we avoid a missed diagnosis? In this article, we provide current-day considerations for the surgical diagnosis of acute abdominal pain.

USE OF ANALGESIC AGENTS DURING THE INITIAL ASSESSMENT

Pain is a universal symptom of acute abdominal conditions. To alleviate suffering, clinicians often provide analgesic agents before the workup is complete, including imaging and surgical consultation. Clinicians vary in their beliefs about whether pain medication masks symptoms and thus delays the diagnosis. In an online survey of 495 surgeons in Germany, 45% of the respondents said that for the majority of their patients, they would provide analgesia before a diagnosis had been established.[9] However, estimates of the effect of pain medications on the masking of clinical symptoms varied. The practice of administering analgesia for patients with acute abdominal pain continues to evolve. In a survey of emergency department physicians, 85% of the respondents thought that conservative administration of pain medication did not change important findings on physical examination, but 76% chose not to prescribe an opiate analgesic until after the patient had been examined by a surgeon.[10]

The literature supports the use of analgesia during the workup for abdominal pain.[12] In 2015, practice guidelines for primary care providers who saw patients with acute abdominal pain supported the judicious use of analgesia during the workup.[11] In practice, however, the timing and dosage of pain medications in relation to imaging and surgical consultation remain uncertain. Even among clinicians who do not believe that pain medication alters the diagnosis or treatment, implementation remains variable.

The administration of pain medications does not appreciably alter the diagnosis or the time to intervention. Multiple studies have evaluated the use of analgesia in adults who present to an emergency department with abdominal pain.[13-17] Although not sufficiently powered to definitively determine the outcome, these studies indicate that analgesia is likely to be safe and effective and that it neither delays the time to diagnosis nor results in increased morbidity and mortality. In a systematic review conducted with the use of MEDLINE and other sources, the administration of opiate analgesics was shown to potentially alter physical examination findings, but these changes did not result in a significant increase in management errors, which were defined as the performance of unnecessary surgery or failure to perform necessary surgery in a timely manner.[18] In these published reports, there were no cases of major morbidity or death attributable to opiate administration.

Several prospective, randomized trials have supported these findings. In a double-blind, placebo-controlled trial that randomly assigned 71 patients with acute abdominal pain to receive morphine sulfate or normal saline, the administration of morphine sulfate effectively relieved the pain and did not alter the ability of physicians to accurately evaluate and treat the patients.[15] In a randomized, controlled trial comparing meperidine with placebo in 100 patients with lower abdominal pain, the administration of meperidine reduced the intensity of the pain, as reported by the patients on a visual analogue scale, without interference with the clinical diagnosis.[19] In another randomized, controlled trial, which compared papaveretum with placebo in 100 consecutive patients who had clinically significant abdominal pain, early administration of papaveretum reduced the intensity of the pain without interfering with the diagnosis.[14] In a double-blind, randomized, placebo-controlled study comparing tramadol with placebo in 95 patients between the ages of 18 and 60 years who had nontraumatic acute abdominal pain, the preoperative use of tramadol reduced the pain and did not adversely affect the accuracy of the diagnosis or decision making.[20] On the basis of a meta-analysis performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, early analgesia with opiates in patients with suspected acute appendicitis might influence the approach to

treatment but does not appear to alter diagnostic accuracy.[21]

Finally, the lack of standardization in the use of pain medications has meant that underserved patient populations are less likely to receive pain medications than White patients. In a national study, Black patients and patients from other underserved racial and ethnic groups with acute abdominal pain who were seeking care in the emergency department were 22 to 30% less likely than White patients to receive analgesic medications.[22] Pain assessment and treatment recommendations reflect racial bias, as well as false beliefs about biologic differences between Black patients and White patients regarding the sensation of pain.[23]

In summary, we strongly endorse the administration of pain medications in modest dosages in patients with acute abdominal pain. The administration of analgesia is warranted even before diagnostic imaging and surgical consultation and does not appreciably alter the diagnosis or treatment plans.

USE OF IMAGING STUDIES

If the disorder causing acute abdominal pain is at an advanced stage at presentation or if treatment is delayed, the result may be substantial complications or death. Most causes of abdominal pain are benign, but several are time-sensitive.[24] Moreover, symptoms can vary widely, and the findings on physical examination may be unreliable.[4] Given today's diagnostic armamentarium, CT angiography with administration of intravenous contrast material (i.e., contrast-enhanced CT angiography) of the abdomen and pelvis has become the primary imaging technique used to assess acute abdominal pain in nonpregnant adults seen in the emergency department.[4,25] This imaging approach can accurately identify the site of intraabdominal inflammation, perforation, or ischemia, and it has a high positive predictive value for specific abdominal diagnoses.[25,26] In one study, contrast-enhanced CT angiography of the abdomen and pelvis increased the physician's level of diagnostic certainty, reduced the hospital admission rate by 23.8%, and led to more timely surgical interventions.[26] Thus, the radiologist may be the first person to confirm the presumptive diagnosis.[25-27]

The intravenous administration of an iodinated contrast agent improves diagnostic accuracy by detecting a range of possible abdominal disorders (e.g., a liver mass, active bleeding, or an abscess). Although the contrast agent may be withheld because of concerns about a possible sensitivity reaction or induced renal toxic effects, the incidence of contrast-related nephropathy is low. The use of unenhanced CT to avoid the risks associated with intravenous administration of contrast material carries a diagnostic penalty. Abdominal and pelvic CT scans obtained without the administration of contrast material are approximately 30% less accurate than contrast-enhanced CT angiography for the evaluation of acute abdominal pain and the identification of actionable secondary diagnoses.[25] Therefore, the diagnostic risk of withholding contrast material must be considered as part of an informed risk–benefit analysis.[25] An orally administered contrast agent is not a standard component of contrast-enhanced CT angiography in the evaluation of acute abdominal pain.

The care of the patient and surgical consultation are often delayed pending interpretation of imaging studies. Diagnostic images should be quickly transmitted and the findings reconciled among specialists, consultants, and other clinicians. The final interpretation of the images should be readily available so that the appropriate consultation or intervention can commence.[27] Ideally, a process or algorithm should be in place to ensure timely acquisition and interpretation of contrast-enhanced CT angiographic imaging in patients with abdominal pain in order to improve outcomes.[2] A wait of at least 2 hours for the final interpretation by a board-certified radiologist is associated with an increased risk of both systemic complications and death because of delays in surgical consultation and source control.[2]

Delays in patient care should be avoided while images are being interpretated. Making contrast-enhanced CT angiographic studies for abdominal pain a priority read by the radiology service reduces the time to intervention.[2] Revisiting Cope's time-honored tenets in diagnosing acute abdominal pain (i.e., a thorough history and physical examination) will create a high index of suspicion in the clinician's differential diagnosis. Ready

access to advanced imaging can expedite the initiation of a surgical consultation. Earlier surgical consultation, in turn, has consistently been shown to reduce complications and deaths among patients who present with acute abdominal pain.[2]

Plain abdominal radiography lacks diagnostic sensitivity and specificity, as compared with contrast-enhanced CT angiography, in patients with acute abdominal pain.[28,29] However, in certain circumstances (i.e., gross signs of peritonitis on physical examination), plain abdominal radiographs can be used to rapidly identify free air and lead to a prompt surgical intervention.

Ultrasonography and MRI may be used as alternatives to contrast-enhanced CT angiography, but they have drawbacks, including variable sensitivity (in the case of ultrasonography) and availability (in the case of MRI). The role of ultrasonography in the diagnosis of acute abdominal pain is driven by the history and findings on physical examination, including a pelvic examination. In modern practice, ultrasonography is preferred for the diagnosis of acute biliary disease and appendicitis.[6,30,31]

The greatest value of ultrasonography is in the evaluation of pregnant patients, such as in early gestation. The use of ionizing radiation should be avoided whenever possible in these patients. Ultrasonography is the initial imaging test of choice for pregnant patients with suspected appendicitis or other pelvic or gynecologic disorders associated with acute abdominal pain (e.g., a tubo-ovarian abscess, a degenerative ovarian cyst, or a ruptured ectopic pregnancy).[4] These disorders are typically best evaluated with pelvic or transvaginal ultrasonography. Contrast-enhanced pelvic MRI, contrast-enhanced CT angiography, or both may be warranted in the workup of pelvic pain in patients capable of becoming pregnant.[4] Point-of-care ultrasonography has diagnostic and triage potential for a wide range of disorders manifested as acute abdominal pain (e.g., acute biliary disorders, gastrointestinal perforation, acute pancreatitis, colitis, intestinal obstruction, and aneurysms).[32] However, ultrasonography is substantially operator-dependent and is associated with a steep learning curve to ensure operator proficiency and high reliability.[32]

OVERUSE OF IMAGING

The number of CT scans obtained for patients presenting to the emergency department with new-onset, nontraumatic acute abdominal pain has progressively increased over the past several decades. Abdominal imaging may fail to reveal a defined intraabdominal disease. In one study, 20% of scans performed were not indicated in the judgment of third-party radiologists.[1] A recent study showed that routine CT imaging is associated with increased costs, as compared with selective imaging.[2] To date, there is no convincing evidence that the increased diagnostic accuracy of contrast-enhanced CT angiography is associated with an improvement in outcomes, such as a reduced length of stay, fewer complications, and lower mortality, among patients presenting with acute abdominal pain.[2]

In its Choosing Wisely campaign, the American College of Radiology (ACR) espouses the judicious ordering of multiphase abdominal CT protocols.[33] With the aim of preventing the overuse of imaging tests, the campaign is anchored on answering three concerns: why is imaging overused, why is imaging a bad thing, and how can we fix the problem?[34] The Choosing Wisely recommendations focus on the use of evidence-based criteria for ordering imaging studies.[33] Appropriate criteria can be a valuable resource in the effort to reduce unnecessary imaging. These criteria are increasingly being incorporated into decision-support computer algorithms that are linked to the ordering of imaging tests.[34] In the ACR Choosing Wisely initiative, strategies that mitigate the overuse of imaging are coupled with education for physicians regarding the best imaging study for an individual patient's clinical circumstances.[33,34]

OLDER PATIENTS

The U.S. population is rapidly aging. The 2021 American Community Survey estimated that 55,892,014 people in the United States were 65 years of age or older. With a total U.S. population of 331,893,745, this age group represented 16.8% of the population, or approximately 1 in 6 people.[35] Disorders that require emergency general surgery are more common in older patients than in those who are younger. Given the increased risks posed by aging and age-associated

coexisting conditions, prompt and accurate diagnoses are needed in this population.

Contrast-enhanced CT angiography may have particular benefits in an aging population, since older adults may present with an unreliable history, vague abdominal symptoms, an altered sensorium, multiple confounding disorders, a challenging physical examination, and diminished physiological reserve.[2,27] Detection of free air, inflammatory changes, or bowel ischemia on contrast-enhanced CT angiographic studies may facilitate earlier laparotomy and source control, thereby preventing progression to severe systemic illness, organ dysfunction, and even death in this vulnerable population.[2,27]

SURGICAL CONSULTATION

Every effort must be made to avoid delays in surgical consultation because of the associated risk of complications and death. High-quality data that support the role of prompt and effective surgical consultation are limited, but it is logical to assume that prompt surgical consultation facilitates timely intervention and source control, which leads to better outcomes. Undoubtedly, outcomes are improved with prompt intervention and source control. As Cope indicated in his treatise on the acute abdomen, a complete history and thorough physical examination are critical components of any assessment of abdominal pain. Clinical decisions should not be obfuscated by disagreements in the interpretation of radiographic findings. If symptoms are not congruent with the suspected diagnosis, the clinician must reassess and consider alternative diagnoses and treatments.[36,37]

Disparities exist with respect to timely surgical consultation. Awareness of this bias is important in assessing and managing acute abdominal pain. For example, one study showed that Black patients who were enrolled in Medicare had lower odds of receiving a surgical consultation after being admitted from the emergency department with a condition warranting emergency general surgery than White patients enrolled in Medicare.[38] These disparities in receiving a surgical consultation cannot be fully attributed to coexisting conditions, insurance status, socioeconomic factors, or individual hospital–level effects.

For patients with acute abdominal pain, the initiation of a surgical consultation with in-house surgeons has been shown to reduce mortality among patients who present with life-threatening conditions that require emergency general surgery.[2] Unfortunately, around-the-clock availability of consulting surgeons is not a reality in many rural or underserved settings.

AVOIDING COGNITIVE BIASES

Clinical decisions depend on a high level of certainty to lead to the most appropriate action.[24] Despite the recognition that cognitive biases can make us more efficient by deploying mental shortcuts to reach a decision that is both helpful and adaptive, such biases may inadvertently lead to missed diagnoses. In 2002, Daniel Kahneman won the Nobel Memorial Prize in Economic Sciences. His book *Thinking, Fast and Slow* is about how two systems, intuition and slow thinking, shape our judgment.[39] Using principles of behavioral economics, Kahneman explains how to think and avoid mistakes when the stakes are high, such as when patients arrive in the emergency department with acute abdominal pain. Solving complicated problems takes mental work, and the brain uses shortcuts when we are stressed. Clinicians are often required to make rapid decisions and implement diagnostic and management plans in a high-stress environment.[24,36] Many forms of bias lead us to jump to conclusions. When making a decision, we should always consider multiple factors.[39] Clinicians must learn to slow down in order to avoid making poor decisions. In the management of trauma, when there is failure to make progress in the stabilization of an acutely injured patient, we stop and reassess. We slow down and revert to the ABCs (airway, breathing, and circulation) of acute care management to avoid missed diagnoses.

Cognitive biases related to the training, previous experiences, personal beliefs, and clinical expectations of clinicians reflect top-down processing. These biases can lead to the selection of inappropriate data sets that misdirect subsequent reasoning and problem solving.[24] Alternatively, clinicians may fall victim to bottom-up processing biases, erroneously basing the diagnostic and treatment plans on a single clinical, laboratory, or imaging data point (or set of data

points) and thus not recognizing other possible diagnoses.[24] An example is the presence of an elevated serum amylase level in a patient with a known history of alcohol abuse disorder who presents with acute abdominal pain. Acute pancreatitis may quickly become the selected diagnosis. However, patients with other conditions, such as a small-bowel perforation, may also present with acute abdominal pain and an elevated serum amylase level. When we speed up, we are less diligent and fail our patients. Despite the exigencies of time constraints and productivity, in the midst of diagnostic uncertainty, we must force ourselves to slow down because our patients are the ones who suffer.

Both top-down and bottom-up processing biases are affected by a multitude of decision-making issues.[24] Commonly cited operational biases include but are not limited to attribution bias, confirmation bias, and anchoring bias.[24,36,40] Attribution bias occurs when symptoms are attributed to unrelated diagnostic tests on the basis of our beliefs. Confirmation bias is the tendency to search for data that favor our mental model of the presenting condition and recall information in a way that confirms or supports our previous beliefs or values. Confirmation bias can lead to selective marshaling of support for a favored hypothesis. Diagnostic momentum can carry a prehospital presumptive diagnosis to the emergency department, where clinicians may search for evidence to confirm the diagnosis without considering other possibilities in the differential diagnosis. Anchoring bias involves the tendency to rely too heavily on the first piece of information. Pattern recognition of a presumptive disease or condition may result in anchoring bias. Irrespective of the accuracy of that information, the "anchor" becomes a reference point for subsequent judgments.[24,36,40] This phenomenon is particularly rampant in the context of electronic medical records. The effect of cognitive biases is greatest in high-stakes situations when rapid decision making is required, such as in the treatment of patients with an unstable condition and those who have potentially life-threatening disorders.

Croskerry defines six strategies in decision making.[24] The first is pattern recognition, in which past experiences create visual recognitions that drive decision making. The second strategy is ruling out the worst-case scenario. This is a strategy of safety that errs on the side of caution. The third strategy is the exhaustive method: constructing a big net that reflects a high degree of uncertainty, resulting in a large number of possibilities, before attempting to make a diagnosis. The fourth strategy is the hypothetical deductive method (the Sherlock Holmes approach), working from the hypothetical with deductive reasoning and evidence-based elimination of diagnoses. The fifth strategy is the use of heuristics, a type of experiential learning in which rules are developed "on the job." This approach is less precise but faster than other methods, and it is based on practical experience. The sixth decision-making strategy, the study of diagnostic errors and their prevention, is based on the cognitive disposition to respond. This is a causal approach to explaining flawed reasoning — a debriefing after the action has taken place.

Navigating uncertainty and arriving at the appropriate diagnostic evaluation are the mark of a skilled clinician. The goal is to direct care to the right place at the right time with the timely use of radiographic imaging in concert with the physician's diagnostic expertise. The stress and uncertainty of diagnosing acute abdominal pain can be reduced with awareness of one's cognitive biases, effective use of imaging, and timely surgical consultation.[24,36]

SUMMARY

A thorough history and physical examination, the judicious administration of analgesia, effective use of imaging, and timely surgical consultation can lead to the appropriate diagnosis of the acute abdomen. We must remain mindful of our biases so that they do not incite processing errors and result in incorrect diagnoses that can lead to morbidity and death.

The Ishikawa fishbone diagram in Figure 1 depicts a cause-and-effect approach, which incorporates attributions and considerations that are essential for achieving a desirable patient-centered outcome. This fishbone diagram represents our how-to guide for achieving a timely evaluation and diagnosis of acute abdominal pain.[41] The diagram shows multiple factors and relates them to one major effect. The main

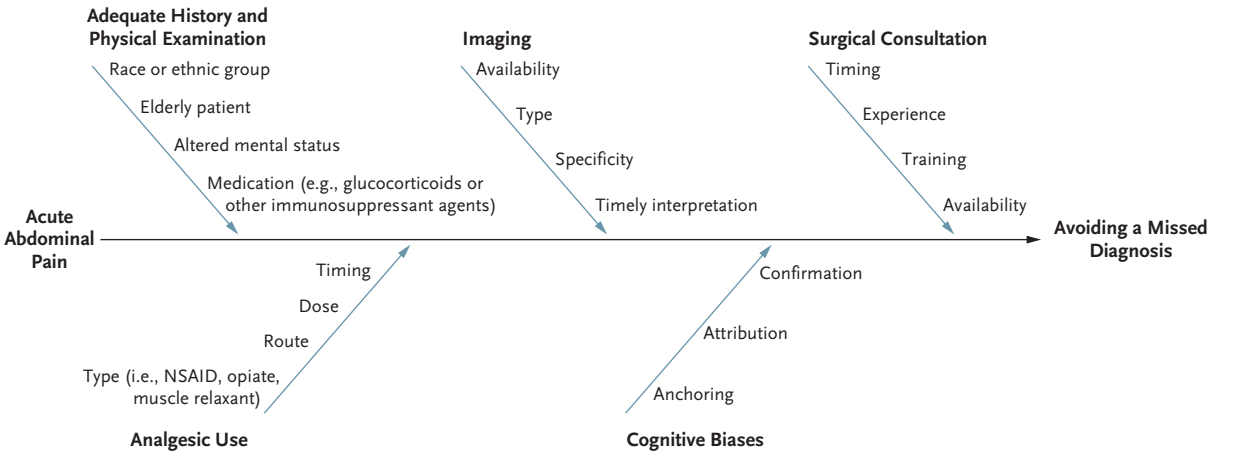

Figure 1. Ishikawa Cause-and-Effect Diagram for Avoiding a Missed Diagnosis in a Patient with Acute Abdominal Pain Warranting Surgical Consultation.

NSAID denotes nonsteroidal antiinflammatory drug.

branches identify the primary causes of the effect. The stems of each main branch indicate contributing factors. For example, the surgical consultation branch has a stem labeled "experience." Other factors could be added, such as the year of residency training or the specialty of the first responder.

CONCLUSIONS

We celebrate 100 years of Cope's seminal *Early Diagnosis of the Acute Abdomen*.[7] Today, we work in teams to manage acute abdominal pain. Cope espoused the history taking and physical examination as the quintessential first step. Unlike Cope, we have real-time access to imaging, and imaging may supplant the first step in diagnosing acute abdominal pain. In both resource-rich and resource-poor settings, surgeons remain the final arbiters of surgical care, which often involves making life-altering decisions under uncertain circumstances.

Cope's axioms still apply today, but what we have seen in the past 100 years is a steadily diminished emphasis on the priority of conducting a thorough and directed history taking and physical examination. As clinicians, our responsibility is to transform the patient's symptoms into signs, and the signs into a differential diagnosis that leads to diagnostic testing, culminating in the appropriate diagnosis and subsequent intervention.

In the future, artificial intelligence or machine learning may have a place in the diagnostic algorithm for the workup of acute abdominal pain, helping to mitigate our cognitive biases. However, Cope's tenets will still form the framework for sound clinical judgment. We hope this review adds value to the memory of Cope's central tenet: the critical importance of the history and the physical examination. Timely access to surgical consultation reduces complications and mortality for patients who present with acute abdominal pain.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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