

**MET**

Mobile Emergency Triage

# Acknowledgments



- Telfer School of Management, University of Ottawa, Ottawa, Canada
- Emergency Department, Children's Hospital of Eastern Ontario, Ottawa, Canada
- Laboratory of Intelligent Decision Support Systems, Poznan University of Technology, Poznan, Poland

# Emergency Triage of Acute Pain Presentations

# What Does Triage Mean?

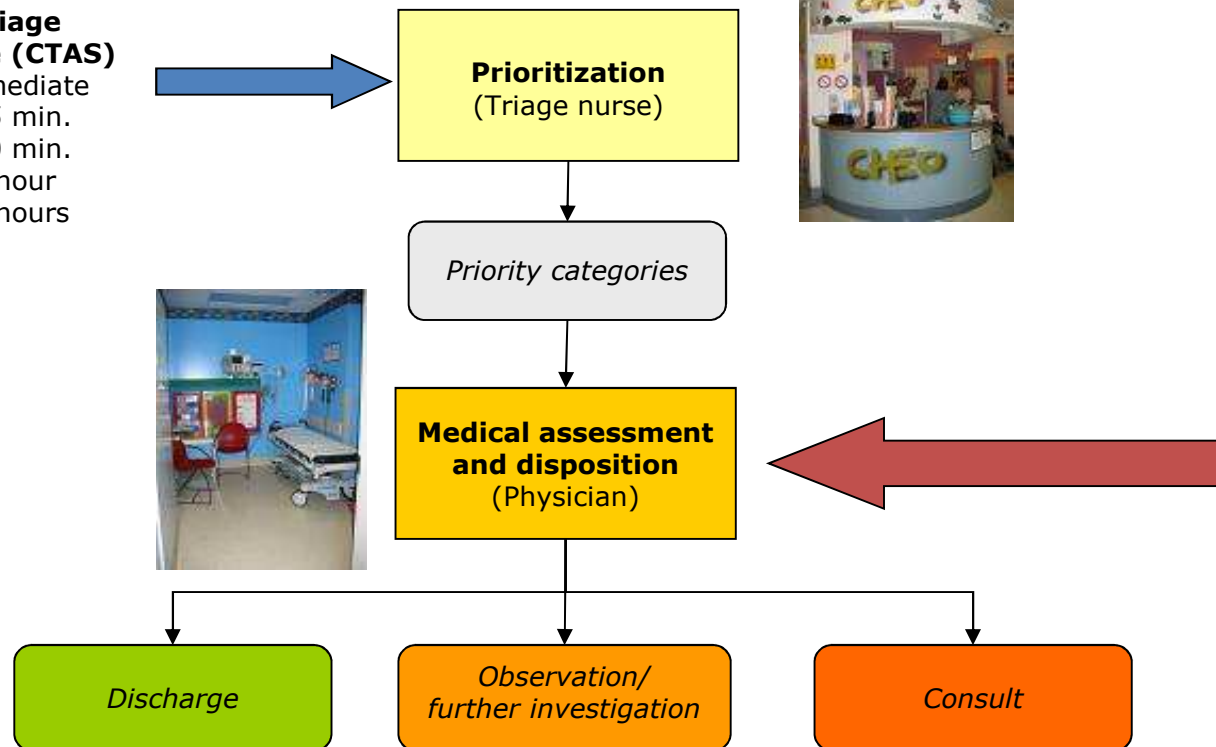
A process for sorting injured people into groups based on their need for or likely benefit from immediate medical treatment. Triage is used in hospital emergency rooms, on battlefields, and at disaster sites when limited medical resources must be allocated

**TRIAGE ≠ DIAGNOSIS**

# Process of Emergency Triage

## Canadian Triage Acuity Scale (CTAS)

- CTAS1 - Immediate
- CTAS2 - ≤ 15 min.
- CTAS3 - ≤ 30 min.
- CTAS4 - ≤ 1 hour
- CTAS5 - ≤ 2 hours



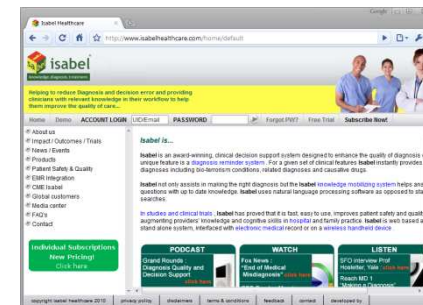
# Triage Support

## Why to support triage?

- To increase triage accuracy
  - Incorrect decision may be dangerous
  - Incorrect decision is expensive (unnecessary consultations and tests)
- To decrease triage duration
  - Examinations and observation may last several hours (150 – 180 min for typical presentations)

# Acute Presentations

- A systematic review of common presentations in the ED failed
  - Limited access to data (even in paper format)
- Interest- and data-driven analysis
  - Despite the interest of physicians difficulties with finding „positive” (sick) patients ⇒ failure of the syncope project
- Many CDSSs used in practice are based on knowledge extracted from medical textbooks – ISABEL (<http://www.isabel.org.uk>)



# Acute Abdominal Pain



# Triage of Abdominal Pain

- Primary cause for surgical consult – appendicitis
- Prevalence (at CHEO)
  - 3300 visits per year (including trauma), i.e., 8-9 children seen daily
  - Approximately 240 children per year are admitted with acute appendicitis
  - A retrospective chart study produced ~ 700 charts
- Extensive studies in the past
  - de Dombal, clinical trials with 16.000 patients
  - Structured data collection/entry more useful than actual decision support

# Available Decision Support Tools

- Appendicitis scores – MANTRELS
- Requires all attributes to be checked and collected
- Not used at CHEO

Table 1  
**MANTRELS Scoring System**

Characteristic	Points
Migration of pain to right lower quadrant	1
Anorexia	1
Nausea and vomiting	1
Tenderness in right lower quadrant	2
Rebound pain	1
Elevated temperature	1
Leukocytosis	2
Shift of white blood cell count to left	1
<b>Total</b>	<b>10</b>

**Recommendations:**

Score < 5	<i>Appendicitis unlikely</i>
Score 5 or 6	<i>Appendicitis possible</i>
Score 7 or 8	<i>Appendicitis likely</i>
Score 9 or 10	<i>Appendicitis highly likely</i>

Source: Alvarado A. A practical score for the early diagnosis of acute appendicitis. *Ann Emerg Med.* 1986;15:557-564.

# Development of a Decision Model

- Rough set theory with **cumulative indiscernibility**
  - Uses approximations of decision classes (patients who do really need consult and patients who may need consult)
  - Handles missing values without any changes to original data (no replacement nor imputation)
  - Presents knowledge in form of comprehensive rules (understood by physicians ⇒ Ottawa Ankle Rule)

# Ottawa Ankle Rule

- An Ankle X-Ray series is only required if:
  - There is any pain in the malleolar zone (defined (more or less) from the tibia and fibula 6 cm above the articulation with the talus, to the bones of the midfoot) **AND** any of these findings:
    - Bone tenderness at the posterior edge or tip of the lateral malleolus **OR**
    - Bone tenderness at the posterior edge or tip of the medial malleolus **OR**
    - Inability to bear weight both immediately and in the ED
- A foot X-Ray series is required only if:
  - There is any pain in midfoot **AND** any of these findings:
    - Bone tenderness at the base of the 5th metatarsal **OR**
    - Bone tenderness at the navicular **OR**
    - Inability to bear weight both immediately and in the ED

# Ottawa Abdominal Pain Rule

- The diagnosis may be *appendicitis* and the management maybe *consult* when one of the following occurs:
  - A male patient experiences right lower quadrant abdominal pain and his white blood cell count is above 20000/mm<sup>3</sup>;
  - A male patient experiences right lower quadrant abdominal pain lasting between 4h and 24h, combined with frequent (more than 3 times) vomiting;
  - ...
- The diagnosis maybe *resolution* and the management maybe *discharge* when one of the following occurs:
  - A patient experiences abdominal pain (neither right lower quadrant nor suprapubic) lasting between 4h and 24h;
  - A patient experiences abdominal pain (neither right lower quadrant nor suprapubic) of intermittent character;
  - ...

# MET1 and MET2 Systems

# MET System (1st and 2nd Generation)



- Facilitates triaging recommendations for presentations of acute pain problems
- Supports triage decision with or without complete clinical information
- Provides mobile support through mobile devices and desktop computers

# MET History (1)

- 1998 – 2000
  - Web-based (PHP + MySQL) application for entering data and triaging patients with abdominal pain

**Abdominal Pain Database**  
Home | Login | Database | Statistics

**Edit Entry**

Date of birth (DOB):  [Today]  
(format: yyyy-mm-dd, e.g. 1989-12-11)

Date of admission (DAO):  [Today]  
(format: yyyy-mm-dd, e.g. 2000-05-02)

Sex:  
 Male N/A  
 Female

Duration of pain:  hour(s) N/A

Location of pain:  
 RLQ N/A  
 Lower abdomen  
 Other

Comments:

Type of pain:  
 Continuous  
 Other  
 N/A

Comments:

**Abdominal Pain Database**  
Home | Login | Original Database | Temporary Database

**Rule:** AbdPainSite=RLQ and PrevVis=no and Guarding=present and LocAbdRebTend=present and Sex=male, **Strength:** 0.19, **Diagnosis:** appendicitis

**Rule:** AbdPainSite=RLQ and Sex=male and AbdPainDuration=low and AbdPainType=other, **Strength:** 0.05, **Diagnosis:** appendicitis

Votes for "resolution"	0.000000
Votes for "appendicitis"	0.240000
Votes for "other"	0.000000

The given case was classified to class : **appendicitis**



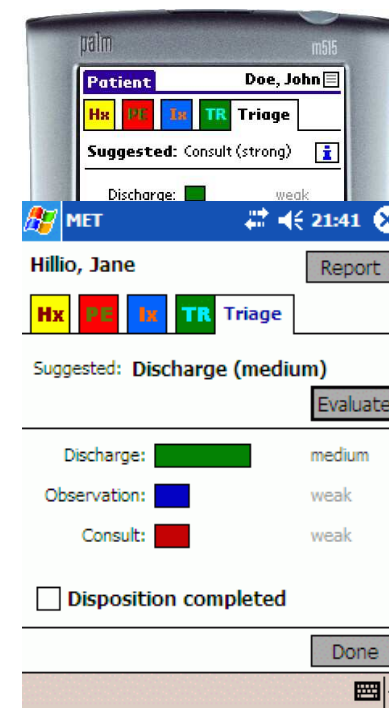
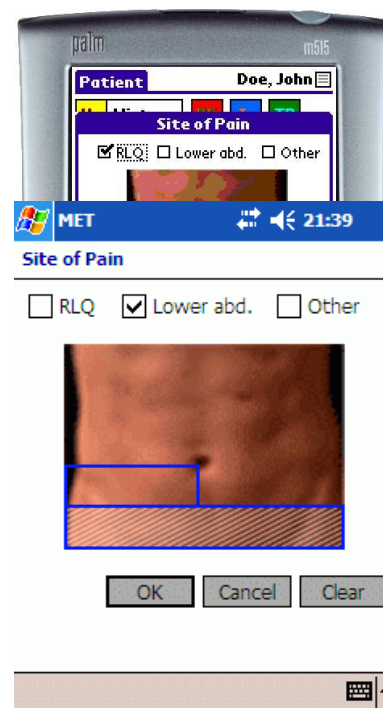
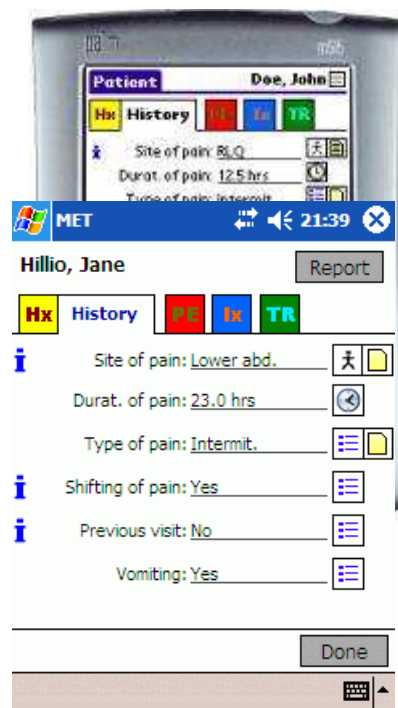
## MET History (2)

- 2000 – 2001
  - The first Palm-based application (MAT → Mobile Abdominal pain Triage)



# MET History (3)

- 2002 – 2003
  - More presentations of pain (MAT → MET1)
  - Support for Palm (Palm OS) and Pocket PC (Windows CE/Mobile)



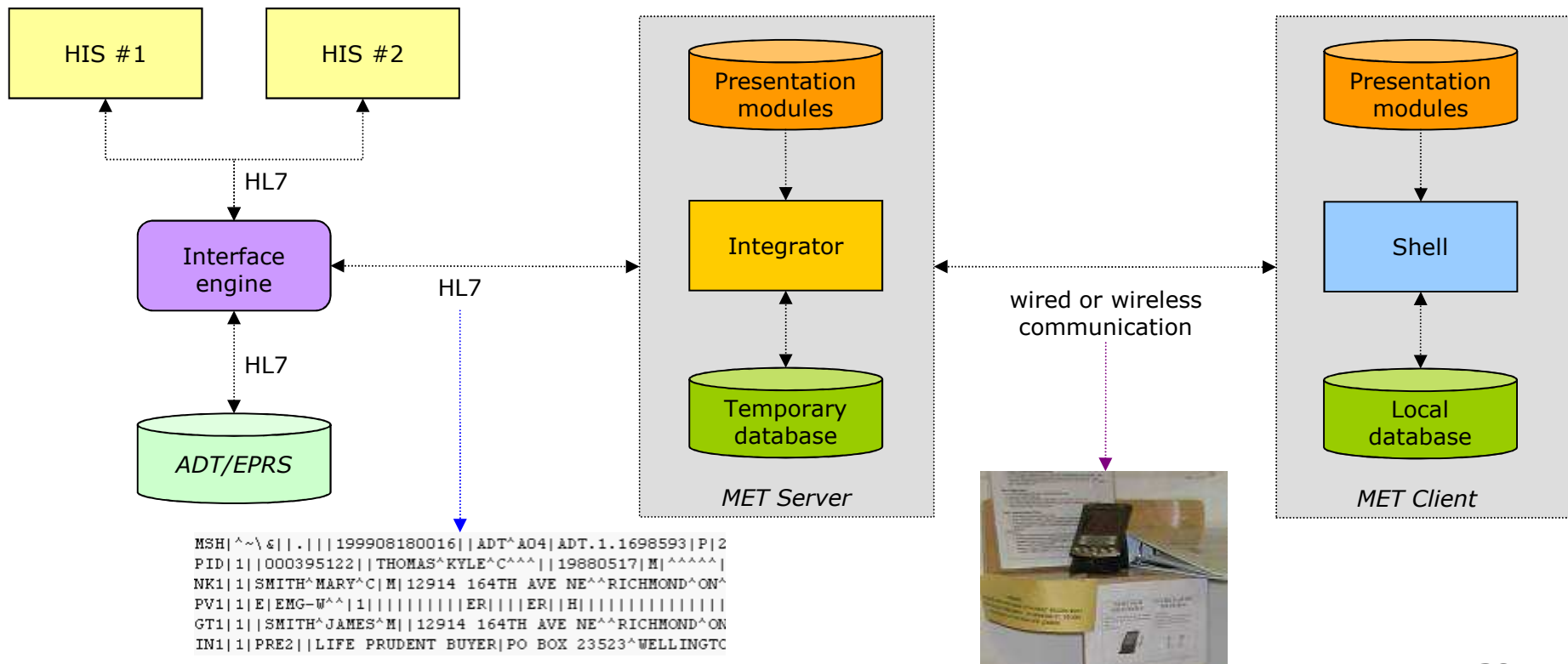
# MET History (4)

- 2004 – 2007
  - Support for desktop and tablet computers
  - Flexible ontology-driven design, Java-based implementation



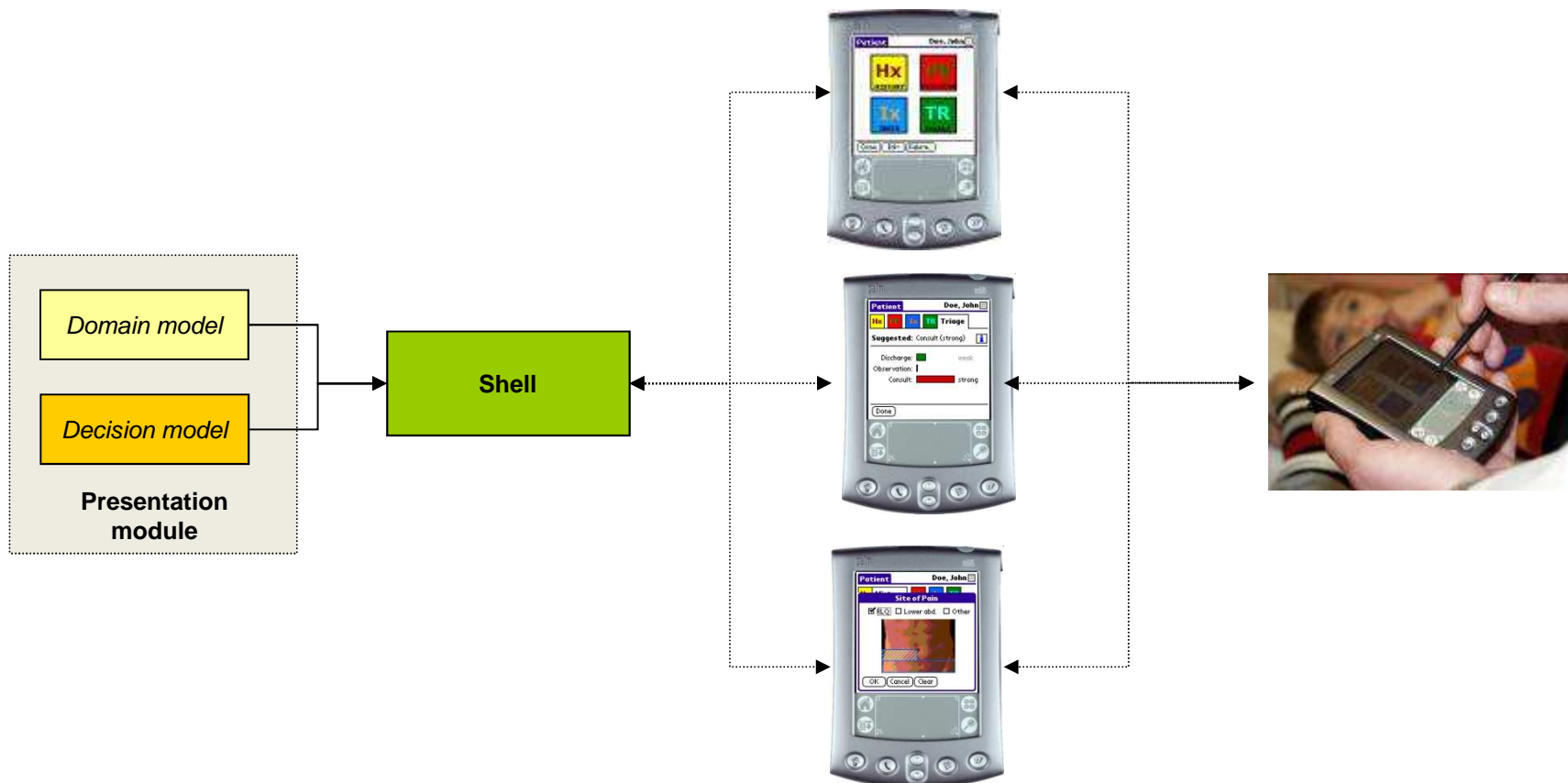
# MET Architecture (1)

Extended client-server architecture for weak-connectivity conditions and integration

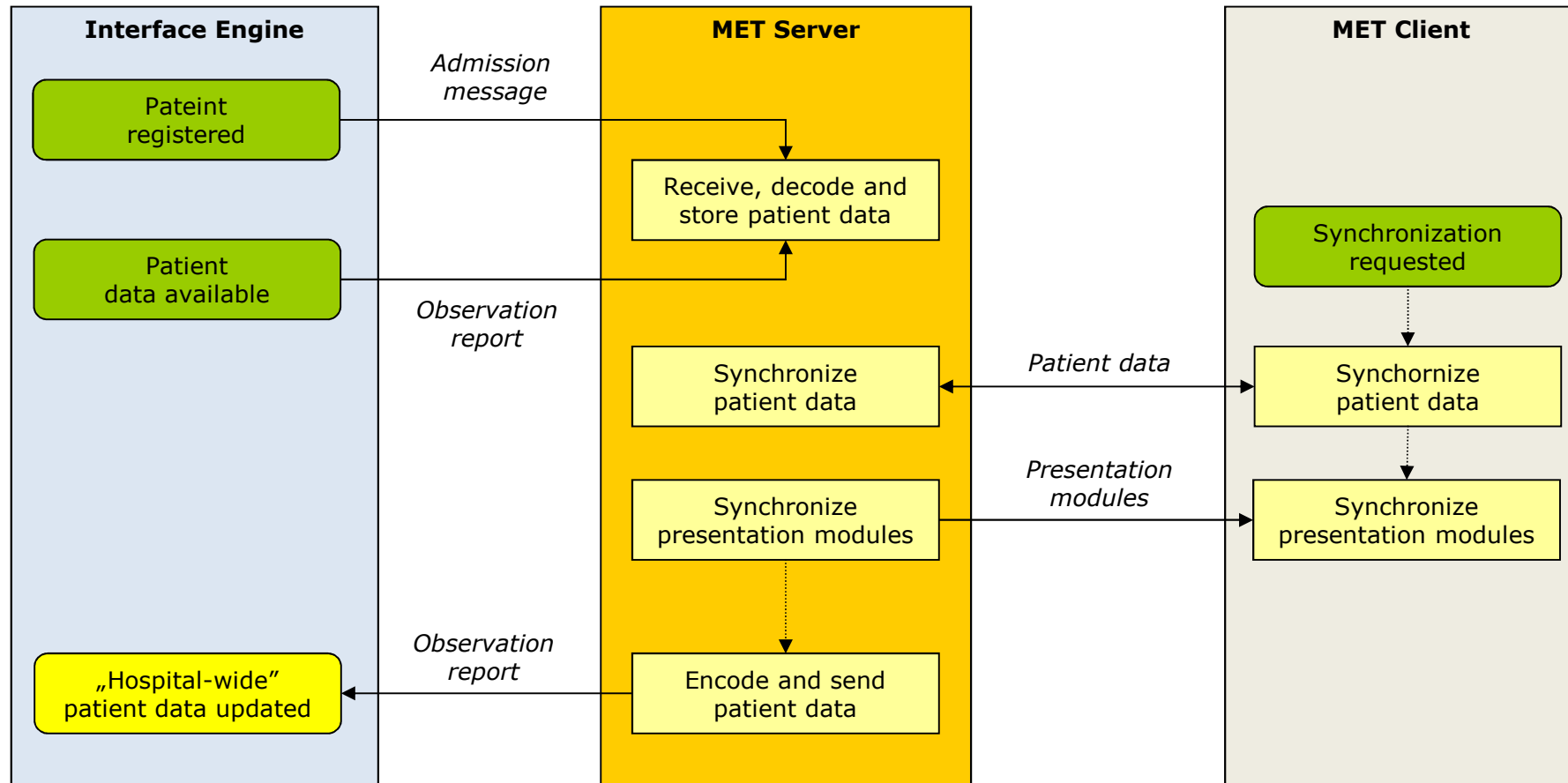


# MET Architecture (2)

Separation of knowledge and solvers for flexibility and reusability



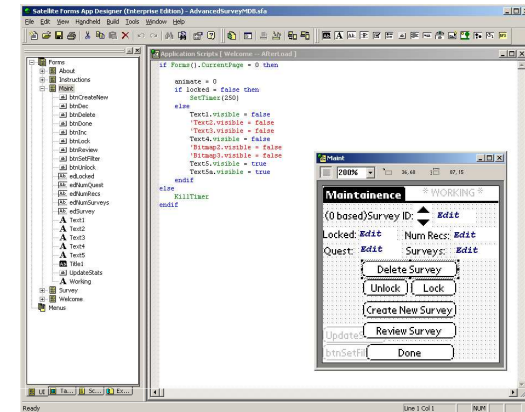
# MET Operations



# Client Technologies (1)

- MAT (pre MET1)

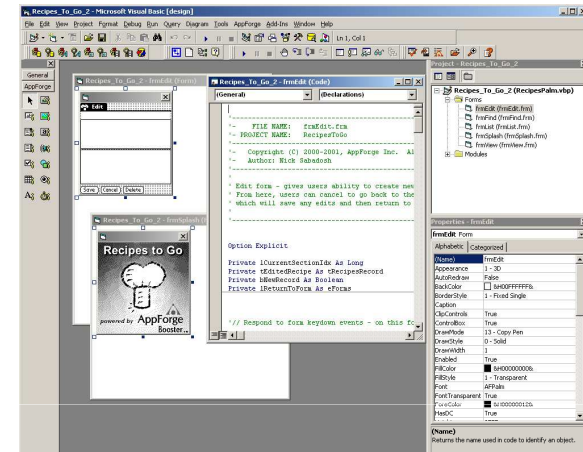
- Implemented in Satellite Forms Enterprise
- Development platform and middleware connectivity layer
- VB-like IDE and language
  - Language limited to simple constructs (no arrays)
  - Limited access to system features (extensions in C++)



# Client Technologies (2)

## ■ MET1

- Implemented in AppForge
- Development platform integrated into Visual Basic 6 or Visual Studio 2003
- Multi-platform run-time environment
  - Virtual machines (Booster) for various platforms and systems (Palm OS, Windows CE, Symbian, RIM)
  - Limited access to native UI controls
- No longer supported – „intellectual property” owned by Oracle

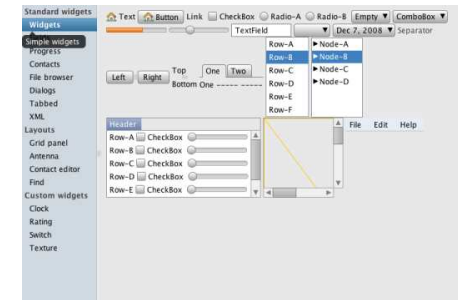




# Client Technologies (3)

## ■ MET2

- Implemented in Java SE (desktop) and ME (CDC, Pocket PC)
- User interface implemented in Thinlet GUI Toolkit
  - Cross-platform Java-based UI library
  - UI declared in XML and created at run-time
- Thinlet is still being developed (<http://www.thinlet.com>) and expanded (support for Android)



# Database/Server Technologies

- SQL Anywhere (iAnywhere Studio)
  - Adaptive Server Anywhere
    - SQL-based server for various platforms
    - Supports „Java in the Database” – Java objects as data types
  - MobiLink
    - Flexible synchronization agent for direct client-server connections
    - Advanced SQL-based scripting for non-standard synchronization techniques (aggregation/scattering of fields and records)
  - SQL Remote
    - Synchronization agent supporting various ways of communication between a server and clients (e-mail, ftp, ...)

# Clinical Trial of MET1-AP

# Clinical Trial of MET1-AP <sup>(1)</sup>

- **Primary goal**
  - To determine and compare the accuracy of MET1-AP and of the ED personnel (residents, staff physicians)
  
- **Secondary goals**
  - To determine the inter-observer agreement (primary and secondary observers) of the assessment of clinical attributes
  - To descriptively estimate the potential savings (time and resources) of following the MET1-AP triage

## Clinical Trial of MET1-AP <sup>(2)</sup>

- Duration of the trial – 8 months (July 2003 – February 2004)
- Required number of patients
  - Total of 640 patients (based on the physician accuracy reported in the literature)
  - 60% cross-over of patients seen by both observers (384 patients seen by residents and 384 seen by physicians)

# Trial Location (1)



- CHEO – Children's Hospital of Eastern Ontario
  - Total pediatric population >400,000
  - 55,000 patient visits in the ED per year
  - 3 pediatric general surgeons (supported by emergency medicine physicians and residents)

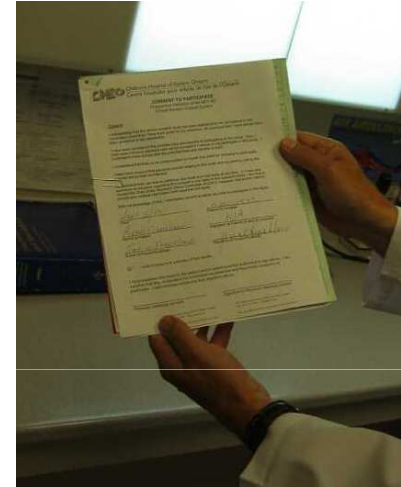


## Trial Location (2)



# Ethical Concerns

- Voluntary participation
  - Written consent that might be rescinded at any time
- No benefit to the patient or ED personnel involved in individual enrollment
  - Prizes for registration clerks and triage nurses who have recruited many patients
- Participation involves no risks to the patient's health or compromise their care in any way
  - MET1-AP recommendations were kept blinded until the final diagnosis was established





# Eligibility of Participants (1)

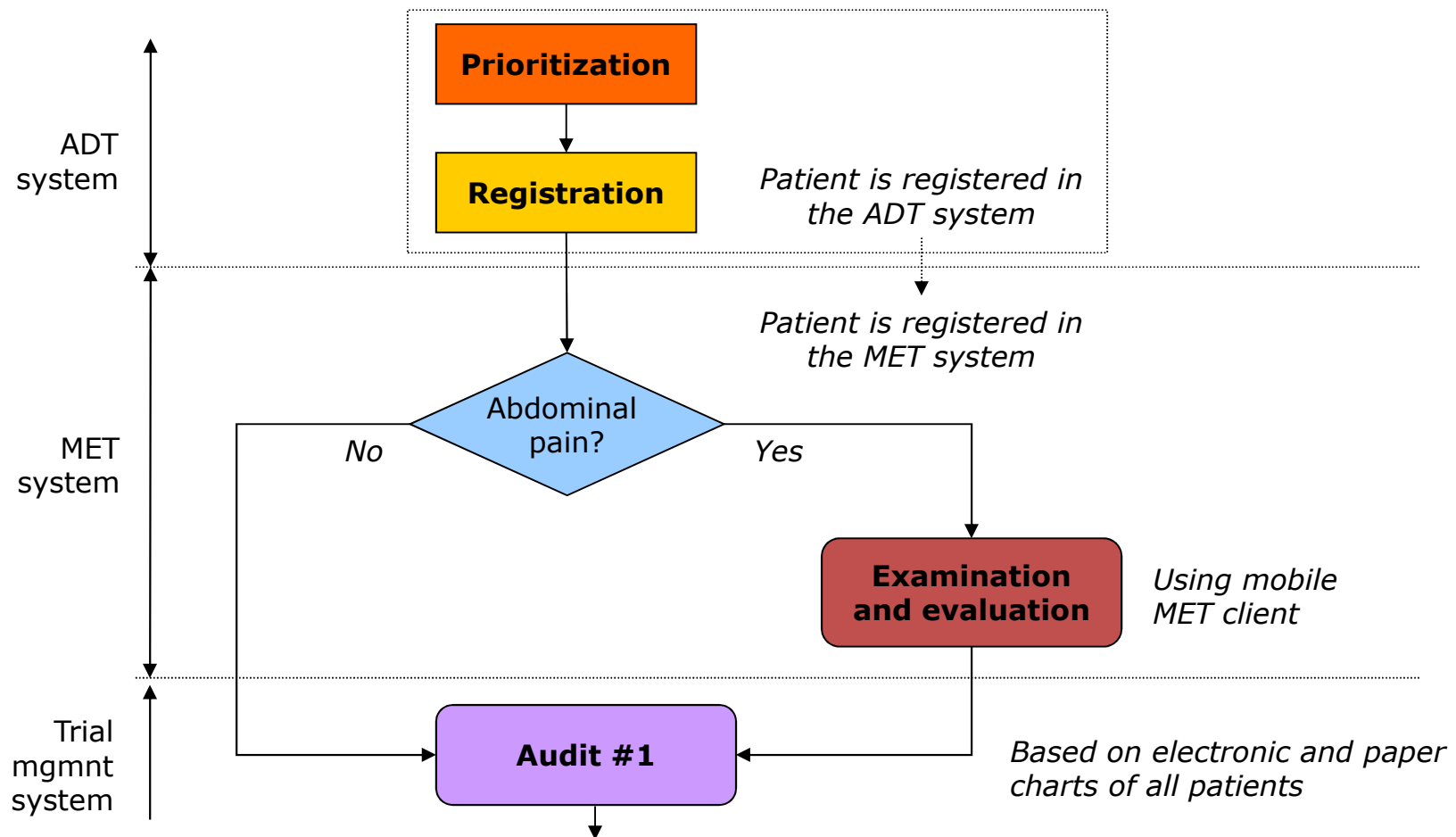
- Not all patients with consent could be enrolled
  - Eligibility checked after receiving consent to participate
  - Patient had to satisfy all inclusion and none of exclusion criteria
- Inclusion criteria
  - Age between 1 and 17 years
  - Presenting complaint of abdominal pain
  - Duration of pain 10 days or less

## Eligibility of Participants (2)

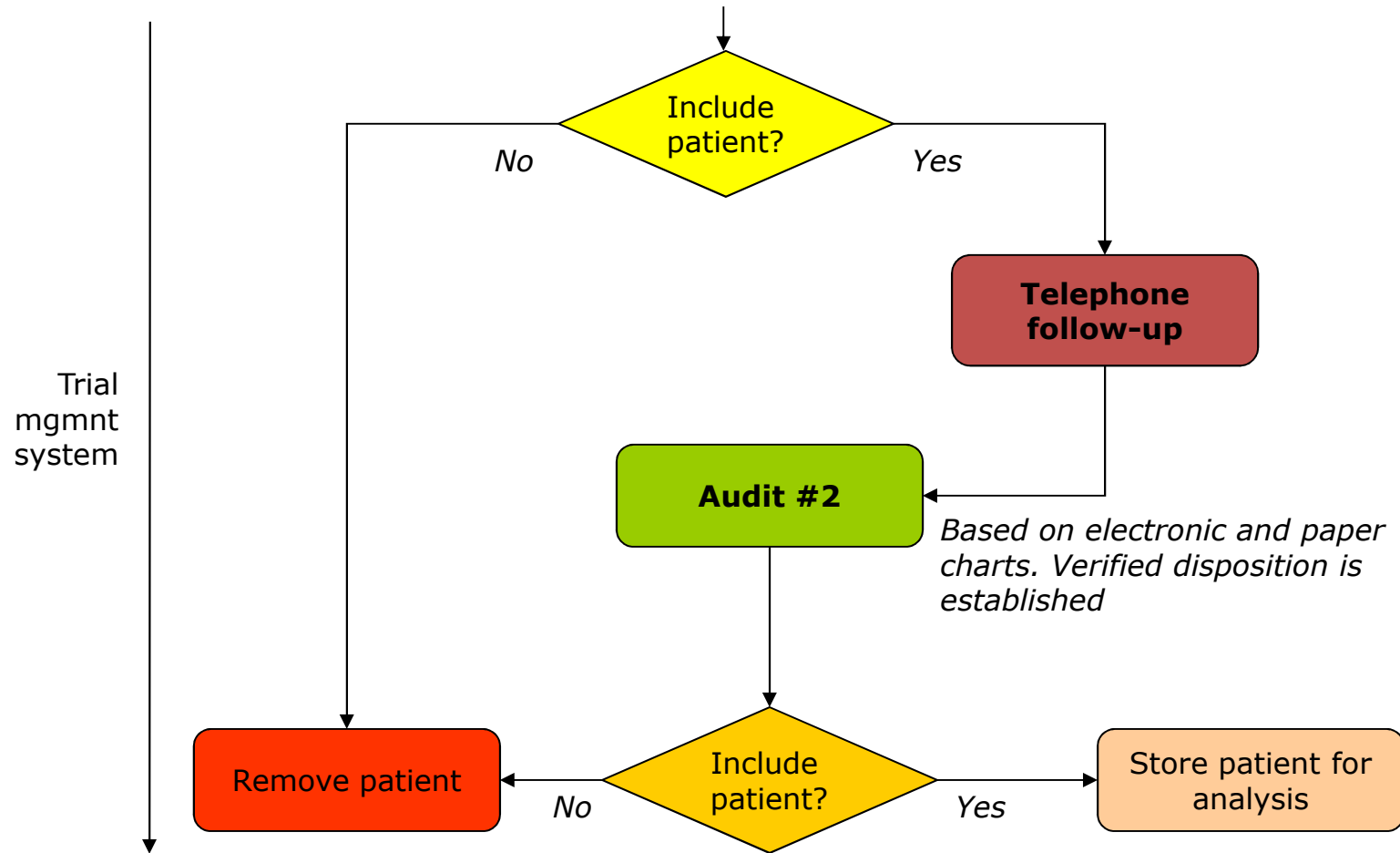
- Exclusion criteria

- Pain as the result of trauma
- Pain potentially caused by an acute disease for which the patient is currently undergoing treatment
- Pain similar to previous episodes explained by a chronic or underlying illness
- Previous abdominal surgery
- Prior enrolment for this episode of abdominal pain
- Direct referral to General Surgery or other consultant service for assessment
- A language barrier (neither English, nor French) or other barrier to complete telephone follow-up

# Trial Flowchart (1)



# Trial Flowchart (2)



# Prioritization and Registration (1)

- Demographic information and presenting complaint is entered into the ADT system (EPIC)
  - Complaint entered as a free text –problems with parsing (abbreviations, spelling errors etc.)
  - One of the unused fields in EPIC was activated and used as a trigger (MET Abd Pain)



# Prioritization and Registration (2)

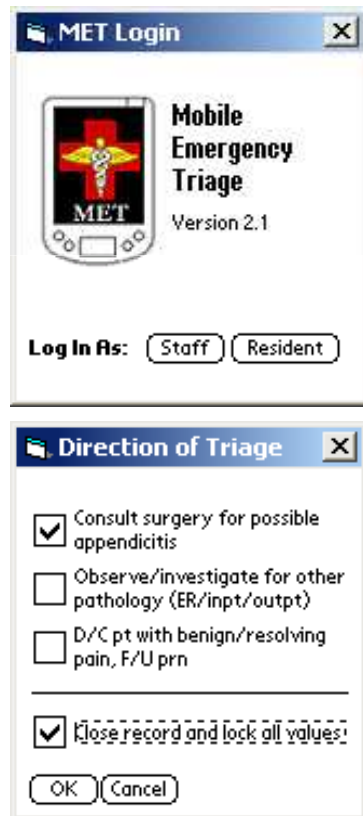
A.P.	ABDOMINAL PAIN RIGHT LOWER QUADRANT	FEVER/DIARRHEA/ABDOMINAL PAIN
ABDOMINAL PAIN	ABDOMINAL PAIN X3 DAYS	LEFT ABDOMINAL PAIN
ABDOMINAL PAIN AND FEVER	ABDOMINAL PAIN, DIZZINESS	LEFT SIDE ABDOMINAL PAIN
ABDOMINAL PAIN & FEVER	ABDOMINAL PAIN, VOMITING, FEVER	LEFT SIDED ABDOMINAL PAIN
ABDOMINAL PAIN & VOMITING	ABDOMINAL PAIN- VOMITING	LETHARGY / VOMITING
ABDOMINAL PAIN - DIABETIC	ABDOMINAL PAIN/ DIARRHEA	MID ABDOMINAL PAIN
ABDOMINAL PAIN - FEVER	ABDOMINAL PAIN/VOMITING/DIARRHEA	NAUSEA / ABDOMINAL PAIN
ABDOMINAL PAIN - FEVER - VOMITING	ABDOMINAL PAIN	R.L.Q. ABDOMINAL PAIN
ABDOMINAL PAIN - RULE OUT APPENDICITIS	BACK PAIN / ABDOMINAL PAIN	RIGHT LOWER QUADRANT ABDOMINAL PAIN
ABDOMINAL PAIN - VOMITING	CONSTIPATION	RIGHT LOWER QUADRANT PAIN
ABDOMINAL PAIN / BACK PAIN	DIARRHEA / ABDOMINAL PAIN	RIGHT LOWER QUADRANT PAIN / ANXIETY
ABDOMINAL PAIN / FEVER	DIARRHEA AND VOMITING	RIGHT UPPER QUAD PAIN
ABDOMINAL PAIN / FLANK PAIN	EPIGASTRIC PAIN	RLQ PAIN
ABDOMINAL PAIN / HEADACHE	FEVER	RULE OUT ABDOMINAL PAIN
ABDOMINAL PAIN / POST ULTRA SOUND	FEVER - VOMITING	RULE OUT DIABETES
ABDOMINAL PAIN / RULE OUT BLOODY STOOL	FEVER - VOMITING - ABDOMINAL PAIN	STOMACK ACHES
ABDOMINAL PAIN / VOMITING	FEVER / ABDOMINAL PAIN	STOMACK CRAMPS & FEVER
ABDOMINAL PAIN FEVER VOMITING	FEVER, ABDOMINAL PAIN	SYNCOPE / SORE THROAT / ABDOMINAL PAIN
ABDOMINAL PAIN INTERMITTENT	FEVER/ ABDOMINAL PAIN	VOMITING & DIARRHEA / ABDOMINAL PAIN
ABDOMINAL PAIN LEFT SIDE	FEVER/ ABDOMINAL PAIN	VOMITING - ABDOMINAL PAIN
ABDOMINAL PAIN RIGHT	FEVER/ABDOMINAL PAIN	VOMITING / ABDOMINAL PAIN

# Examination and Evaluation (1)



- Primary and secondary patient records
  - Entered independently by primary and secondary observers
  - Each observer asked for consent and checked patient's eligibility

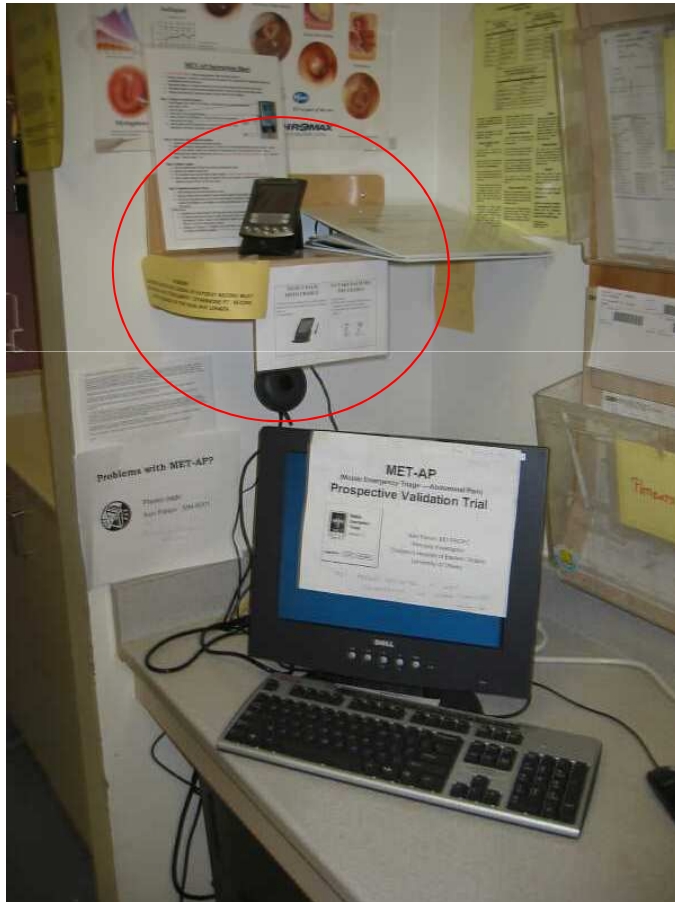
## Examination and Evaluation (2)



- Authentication limited to two classes of users (physicians and residents)
  - Too many users (around 150) to support their management and easy „personal” logging in
- It was very difficult to establish proper wording for the triage screen
  - Once the wording was established, it was too long to fit it the small screen




# Problems with Synchronization



- Because of hardware and organizational limitations we were not able to use wireless networking
- Failures of cradles
- Incorrect placing handhelds on cradles (⇒ human factor)

# Audit #1

- Filtering patients for further analysis
- Identification of missed eligible patients

Logged as **Szymon Wilk**      User Type **Administration**      Patient Summary       Log Out

---

Where do you want to redirect this audit?      Disposition      Extra Note


ER Diagnosis

Visit Info

File Number	First	Middle	Last	Is Eligible	Is Approached	Has given consent	Visit Date
2022	Claudia	B	Laurin	False			10/28/2003 8:34:00 AM

# Telephone Follow-up (1)

- Collecting additional information about patient's history following the ED visit
- Recording additional assessments and resources required by a patient after the ED visit

Logged as [Szymon Wilk](#)      User Type **Administration**      [Patient Summary](#)  Log Out

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**Name of the Patient : Claudia B Laurin**

---

Did your child's pain resolve before leaving the hospital (either ER or after inpatient admission)?       Yes    No

Has the pain recurred at any point in the last 10 days?       Yes    No

---

**Has your child had any of the following symptoms since leaving hospital, either with abdominal pain or without?**


vomiting	<input checked="" type="checkbox"/>	diarrhea	<input type="checkbox"/>
constipation or painful defecation	<input type="checkbox"/>	fever	<input checked="" type="checkbox"/>
painful urination or flank pain	<input type="checkbox"/>	... ..	<input type="checkbox"/>

# Telephone Follow-up (2)

Logged as **Szymon Wilk**

User Type **Administration**

Patient Summary

 Log Out

Name of the Patient : **Claudia B Laurin**


Have you sought further medical assessment or had any further tests since your ER visit?  Yes  No

Assessment Type	Location	Result	Date
GP or Pediatrician	Ottawa, Bank Street	flu	<a href="#">03/11/2003</a>
			<a href="#">03/11/2003</a>
			<a href="#">03/11/2003</a>
			<a href="#">03/11/2003</a>
			<a href="#">03/11/2003</a>

Resource	Pre-Decision	ER	Post-Decision	ER	Post-Decision	In Patient	Post-Decision	Out Patient	
Lab-Bld	1		0		0		0		Edit
Lab-Urine	0		0		0		0		Edit
IV/S_L	0		0		0		0		Edit
Oral Med	0		0		0		0		Edit
IV Med	0		0		0		0		Edit

# Audit #2

- Establishing verified triage disposition (used as the gold standard for calculating triage accuracy)
- Filtering patients for final study

Logged as [Szymon Wilk](#) User Type **Administration** Patient Summary  Log Out

---

Name of the Patient : **Claudia B Laurin**

Where do you want to redirect this audit?

Final Categorization

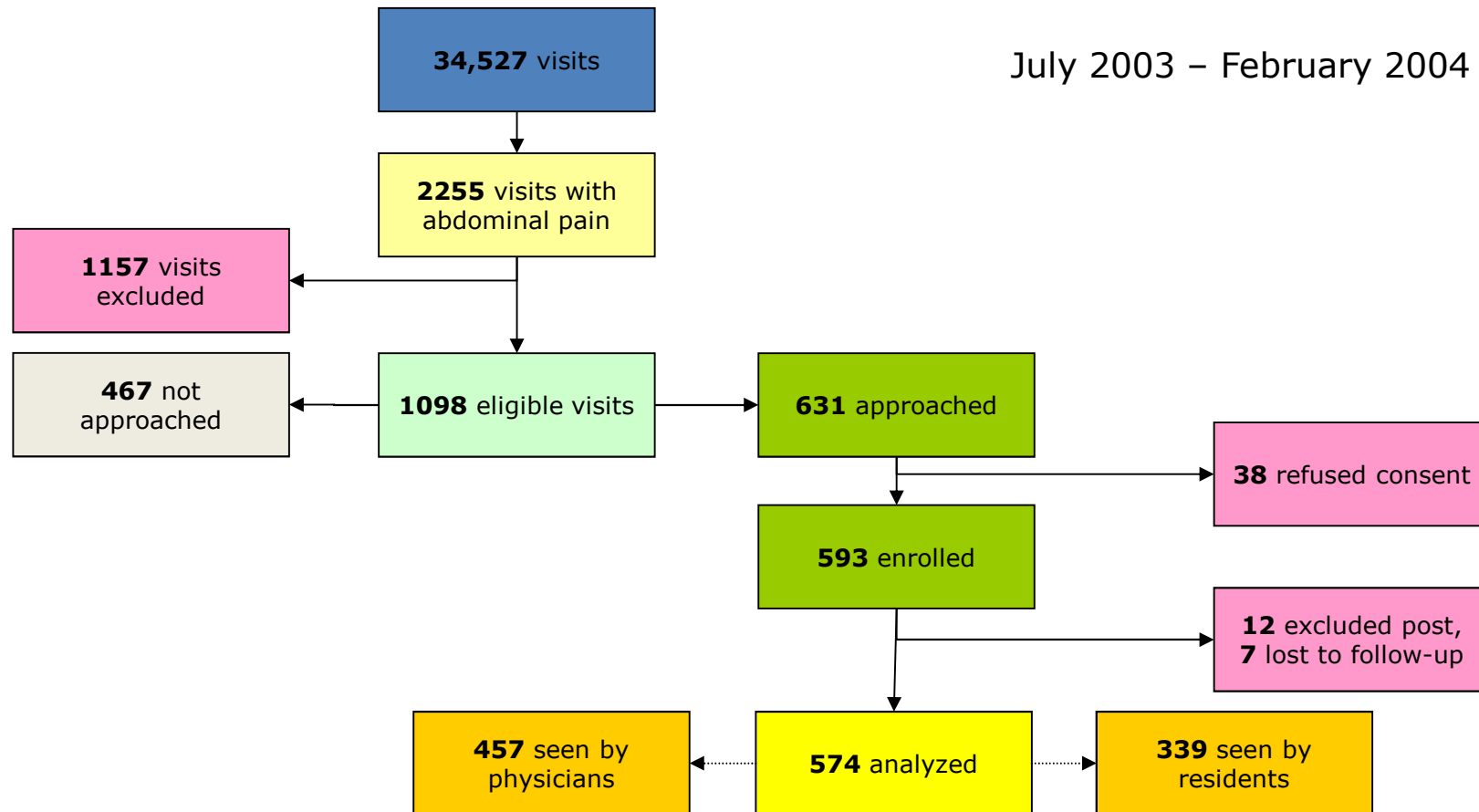
ER Diagnosis  
appendicitis is suspected

SUBS Diagnosis  
flu

Extra Note  
pain resolved in the ER

# Enrolled Patients

July 2003 – February 2004



# Inter-Observer Rates <sup>(1)</sup>

- Inter-observer reliability (Cohen's kappa) of assessment for clinical attributes
  - Calculated for 222 patients seen by both observers
  - Kappa > 0.70 considered as satisfactory

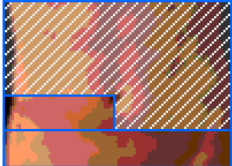
Attribute	Kappa
Duration of pain <sup>D</sup>	0.825
Localized guarding	0.309
Previous visit	0.481
Rebound tenderness	0.449
Shifting of pain	0.521
Site of pain	0.513

Attribute	Kappa
Site of tenderness	0.573
Temperature <sup>D</sup>	0.945
Type of pain	0.475
Vomiting	0.890
WBC <sup>D</sup>	0.952

# Inter-Observer Rates (2)

**Site of Tenderness**

RLQ  Lower abd.  Other



OK Cancel Clear

**Information**

**i** **Shifting of pain**  
Pain historically moving from anywhere in the abdomen to site of maximal pain

OK

**Information**

**i** **Localized guarding**  
Localized muscle sustained contraction noted when palpating the abdomen

OK

## Possible explanation of inconsistencies

- Patient's state changes in the ED
- Patient or parents give different answers to different observers
- Residents are not experienced enough to collect valid values of some attributes
- Constrained data entry on MET and free entry on a chart may lead to ambiguous „mappings“
- Users make mistakes when entering data (e.g., duration of pain – fixed later)



# Triage Accuracy (1)

MET

Hillio, Jane

Report

Hx PE TR Triage

Suggested: Discharge (medium)

Evaluate

Discharge:  medium

Observation:  weak

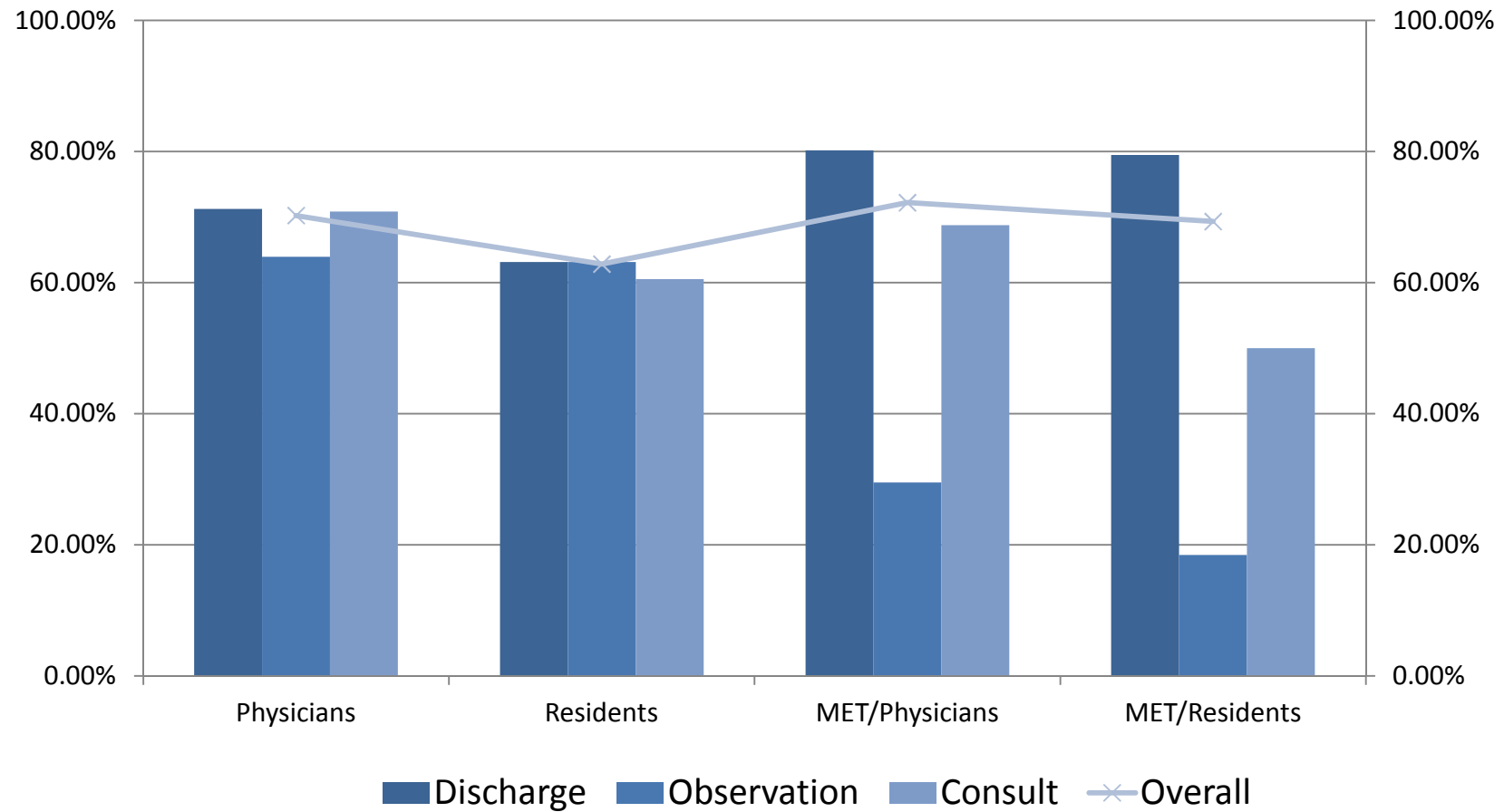
Consult:  weak

Disposition completed

Done

- MET works as an assistant
  - Provides strengths for all possible triage dispositions
  - Marks the strongest disposition as a suggested one (physician does not have to follow it)
- The suggested disposition was considered an ultimate one and compare to a gold standard (from Follow-up #2)

# Triage Accuracy (2)



# Triage Misclassifications

## Physicians

	Discharge	Observation	Consult
Discharge	248	85	15
Observation	16	39	6
Consult	1	13	34

## MET1-AP/Physicians

	Discharge	Observation	Consult
Discharge	279	39	30
Observation	38	18	5
Consult	12	3	33

## Residents

	Discharge	Observation	Consult
Discharge	166	80	17
Observation	11	24	3
Consult	2	13	23

## MET1-AP/Residents

	Discharge	Observation	Consult
Discharge	209	31	23
Observation	23	7	8
Consult	14	5	19

# Broad Triage Categories

- Broad observation category
- Multiple possible diagnostic outcomes bound to a single triage outcome

Hernia	Leukemia	Urinary Tract Infection
Intussusception	Inflammatory Bowel Disease	Nephrolithiasis
Volvulus	Infectious Colitis	Ovarian Torsion
Bowel Obstruction	Intra-abdominal Abscess	Ovarian Cyst
Mesenteric Adenitis	Malabsorptive Syndromes	Testicular Torsion
Gastritis, Ulcer Disease	Porphyria	Epididymitis
Hepatitis	Toxin Ingestion	Diabetes
Biliary Colic, Cholecystitis	Pneumonia, Asthma	Other Metabolic Derangements
Pancreatitis	Group A Strep Pharyngitis	Sickle Cell Crisis
Ingested Foreign Body	Abdominal Wall Contusion	Henoch-Schonlein Purpura
Intra-abdominal Neoplasm	Hemolytic Uremic Syndrome	

# Latent Attributes <sup>(1)</sup>

Physicians were asked to triage patients using only information supplied to MET1-AP

Gold standard	ED	Post-ED	MET	Comment
discharge	discharge	observation	discharge	would want to see urine, preg test if >12, menstrual hx, bowel movement history; Constant nature with rebound is worrisome
discharge	observation	discharge	observation	likely viral
consult	observation	discharge	discharge	
consult	observation	discharge	observation	likely viral
discharge	consult	consult	observation	Would want to also rule out ovarian torsion
discharge	consult	discharge	consult	
observation	observation	discharge	discharge	
discharge	discharge	discharge	discharge	
observation	observation	discharge	consult	
observation	observation	observation	observation	would want to assess for resp symptoms

# Latent Attributes (2)

Gold standard	ED	Post-ED	MET	Comment
observation	discharge	observation	consult	would want to see urine, preg test if >12, menstrual hx, bowel movement history; Constant nature in Lower abd >24 hours
observation	observation	observation	observation	would get an U/S
consult	consult	consult	consult	
observation	observation	observation	consult	? early appendix - would get U/S
consult	consult	consult	consult	
observation	consult	observation	observation	CXR, though likely still benign (D/C)
observation	consult	observation	observation	Same as above - without more info, I can't classify them differently.
observation	observation	discharge	discharge	
consult	consult	observation	discharge	would get an U/S
observation	observation	discharge	observation	

## Conclusions from the Trial

- Decision rules provided a comprehensible and readable representation of discovered clinical knowledge
- A successful decision support tool has to be available at the point of care and needs to be integrated with electronic patient record
- Accuracy of the system was comparable to accuracy of physicians, however, the system was less conservative ⇒ imbalanced data, latent attributes, broad categories
- Clinical experience and acumen is still necessary!