Enhanced Clinical Summarization in the Intensive Care Unit using a Novel Medical Record timeLine (MeRLin)

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Vitaly Herasevich, MD, PhD - Research Mentor

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Plymouth, MN
May 24th, 2017
Disclosures

- The authors have no conflicts of interest to disclose relating to this research
Personal impetus for this research

- Internal Medicine resident ➔ Pulm/ICU Fellow

- **Frustration** with inefficiencies in EHR data display/aggregation
  - Time spent at computer vs bedside

- Experience in programming/web-design ➔ ability to design+implement novel tool
Learning Objectives

1. Learn the importance of clinical information gathering habits among clinicians
2. Enumerate the difficulties faced by clinicians performing electronic health record review
3. Review methods for clinically-oriented organization and prioritization of EHR metadata
4. Appraise a novel critical care information display system
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Clinical information gathering - *where*

- *How do we practice? – as a process*

- History → Exam → Differential?

- Computer → Computer → (patient) → Differential?

- Inefficiencies in the process?
Clinical information gathering - *where*
Clinical information gathering - *where*

- EHR is the most common initial source of information on new patients\(^1\)

---

Clinical information gathering - *where*

- IM residents post-ACGME duty hours change

<table>
<thead>
<tr>
<th>Activity</th>
<th>Total</th>
<th>Site 1 (%)</th>
<th>Site 2 (%)</th>
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<tr>
<td>Total time (hours)</td>
<td>873</td>
<td>439 (50.3%)</td>
<td>434 (49.7%)</td>
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<tr>
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<td>12.3%</td>
<td>11.4%</td>
<td>13.3%*</td>
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<td>3.8%</td>
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<td>Follow-up patient visit</td>
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<td>6.5%</td>
<td>7.8%*†</td>
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<td>0.1%</td>
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<td>2.8%</td>
<td>1.3%*†</td>
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<td>Rounds</td>
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<td>7.3%*†</td>
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<td>1%</td>
<td>0.3%</td>
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<tr>
<td>Indirect patient care</td>
<td>63.6%</td>
<td>61.2%</td>
<td>66.1%*</td>
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<tr>
<td>Reviewing patient chart</td>
<td>14.5%</td>
<td>14.7%</td>
<td>14.3%</td>
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</tbody>
</table>

- 15% of 12 hrs ≈ 2 hours of chart review daily

Clinical information gathering - *where*

- Consistently 40-60% of time in “indirect care”
  - = EHR use in modern era
- Dose-response by training level:
  - Interns: 85%

Clinical information gathering - *where*

A Time-Motion Study of ICU Workflow and the Impact of Strain*

Yosefa Hefter, BA; Purnema Madahar, MD; Lewis A. Eisen, MD; Michelle N. Gong, MD, MS

- “Review” of electronic patient data = 20% time
- Direct patient care = 17% time
- Any computer interaction = 37% time
  - $\times 12$ hours = $4.5 \text{ hours}$

Clinical information gathering - *where*

“A Time-Motion Study of ICU Workflow and the Impact of Strain”

Yosefa Hefter, BA; Purnema Madahar, MD; Lewis A. Eisen, MD; Michelle N. Gong, MD, MS

“Developing efficient communication and computer systems is necessary to facilitate maximum allocation of time to delivery of high-quality care.”

Clinical information gathering - *where*

- ICU work pre/post EHR implementation (Epic)

<p>| Table 3 – Time distribution of tasks performed by residents in ICUs before and after EHR implementation. |
|-----------------------------------------------------|-------------------------------------------------|----------------------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Pre ($n = 40)^a$</th>
<th>Post ($n = 37)^a$</th>
<th>t-Test (p-value)</th>
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<tbody>
<tr>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
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<tr>
<td>1 Direct patient care</td>
<td>30.8%</td>
<td>12.4%</td>
</tr>
<tr>
<td>1.1 Physical care of patient</td>
<td>4.9%</td>
<td>4.7%</td>
</tr>
<tr>
<td>1.2 Use of monitors and devices</td>
<td>1.0%</td>
<td>1.1%</td>
</tr>
<tr>
<td>1.3 Patient conversation</td>
<td>0.6%</td>
<td>1.3%</td>
</tr>
<tr>
<td>1.4 Order management including medications</td>
<td>6.6%</td>
<td>4.3%</td>
</tr>
<tr>
<td>1.5 Clinical review and documentation</td>
<td>17.7%</td>
<td>13.0%</td>
</tr>
</tbody>
</table>

- Similar rates/changes among attendings

Clinical information gathering - *where*

- Clinical information is more-often obtained from the EHR than the patient
  - At least as a function of time spent

- Increasingly, we “care” for patients at the computer, not the bedside
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Clinical information gathering – *how/why*
Clinical information gathering – *how/why*

- Most EHRs are ‘paper’ charts in electronic format
  - Labs listed with labs, images with images
  - Data siloed into tabs/screens
    - Based on *data-archive model*
Clinical information gathering – *how/why*

<table>
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<tr>
<th>Service Description</th>
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<th>Status</th>
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</table>
Clinical information gathering – *how/why*

- What are clinicians *doing* in the EHR?
- Goals/use-cases?
Clinical information gathering – *how/why*

1. Data retrieval
   1. Specific data = test result, consult note
   2. General “chart review” for unfamiliar patients
2. Order entry
3. Care coordination/communication
4. Clinical decision support (?)

Clinical information gathering – *how/why*

- System design for focused data retrieval/display
  - EASY

- Users learn/adapt to poorly designed systems

- “What did the echocardiogram show?”
  - Diagnostics tab →
  - sort by “Cards” →
  - scroll to “Echo” →
  - click “Report”
Clinical information gathering – how/why

- System design for general “chart review”
  - HARD

Clinical information gathering – how/why

• “Chart review” or “chart biopsy”…?

biopsy’, and which we define as ‘the activity of examining a patient’s health record to orient oneself to the patient and the care that patient has received in order to inform subsequent conversations about or care of the patient’. Drawing on

**Clinical information gathering – how/why**

<table>
<thead>
<tr>
<th>Function</th>
<th>Representative quotations</th>
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</table>
| Getting an overview of the patient           | ► It just gives you kind of an overall gist of the patient. Of how likely—I guess it just helps put them on the continuum of sick versus not sick, which is kind of what you first develop or your reaction  
   ► Field note excerpt: [The participant] sees recent notes from a physician she recognizes by name and knows to be an oncologist, so she presumes the patient has cancer |
| Preparing for handoff and subsequent care    | ► I’m also thinking, ‘What are they going to need when they go home?’ I have to have those questions in mind right from the get-go, even when I’m admitting, even sometimes at the point of the chart biopsy, so that I can anticipate their care  
   ► Field note excerpt: [The participant] tells me he is forming a differential diagnosis. Things he will be listening for in the handoff in hopes of confirming or ruling out |
| Defending against potential biases          | ► It’s like buying a car. You don’t just take the dealer’s word  
   ► I just do what we call the chart biopsy real quick, and then I call back and get the story. Because again, … what they think is going on might not be accurate |

Clinical information gathering – *how/why*

- Chart review = *building the patient’s story*
  - “Vitally important skill”

When the EHR was implemented, clinicians reported that two highly problematic obstacles had been generated: the EHR fragmented data interconnections - described elsewhere as the loss of data connectivity [34], and multiplied the sheer amount of data available to the clinician. These obstacles impeded clinicians’ abilities to engage in *building the patient’s story*.

Clinical information gathering – how/why

• “scattering … elements … into different screens and content categories”
• “hid the connections between patient data”

Clinical information gathering – how/why

Figure 2. The average percent of time that physicians spent on each section of the EHR.

summarization process based primarily on what the physicians said while creating the summary using a think-aloud protocol. We coded tasks that the physicians set as they moved through the EHR and, using Morae, we marked the instances in the recordings where these goals were executed.

Results

Clinical information gathering - how

<table>
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<tr>
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</tbody>
</table>

Dictated Documents information is temporarily unavailable. Due to this, the list may be incomplete. Please click [Refresh] button.
Clinical information gathering - *how*

- Clinicians switch back/forth between tabs/screens constructing a mental model

- Clinical informatics $\rightarrow$ we can do better
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Longitudinal Clinical Summarization

• “Dashboard” ≠ Longitudinal Clinical Summary
  • Snapshot vs story
Longitudinal Clinical Summarization Research


Longitudinal Clinical Summarization Research

- Single vs multi-patient

- Problem/organ-system-centric vs chronologic
  - Hybrid?

- Emphasis on structured (numeric) vs unstructured (text) data
Longitudinal Clinical Summarization Research

- LifeLines

<table>
<thead>
<tr>
<th>Summary</th>
<th>Betablocker</th>
<th>Phenothiazine</th>
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<td>After zooming</td>
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<td></td>
<td>Propanolol</td>
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</tr>
<tr>
<td></td>
<td>Prochlorperazine</td>
<td>Promethazine HCL</td>
</tr>
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</table>

**Figure 5:** Example of summarization for four drugs in two classes.

**Figure 4:** Details of three prescriptions’ actual and expected duration. Estimated (i.e. calculated) refill dates can show possible overuse (chloral hydrate) or under-use (Dilantin) of the medication.
Longitudinal Clinical Summarization Research

- KNAVE (II)
  - “Knowledge-based Navigation of Abstractions for Visualization and Explanation”

Longitudinal Clinical Summarization Research

• TimeLine → AdaptEHR


We saw Mr. Smith in the Bowyer Oncology Clinic today. This is a 50-year-old Caucasian male with a diagnosis of glioblastoma multiforme as of June 2003. At point of diagnosis, the patient underwent resection for tumor removal from the right temporal lobe, and subsequent radiation therapy for six weeks. He was started on BCNU chemotherapy every 4 weeks, and continues to respond well to the treatment. MR scans from the past week show no tumor progression; the affected region appears stable. There is no evidence of edema present. However, MR perfusion imaging continues to show uptake of BCNU in the region. The DTI study was unremarkable. Physical examination was normal; the patient’s Karnofsky score is 100. Treatment plan: We will continue with the 6-week cycle of BCNU, with follow-up in 12 weeks. An MR scan with perfusion study will be ordered at that time.
Longitudinal Clinical Summarization Research

- CLEF
  - Clinical e-Science Framework

Name: Nora Batty
Sex: Female
Date of birth: 01-01-1935

Events selected: Bilirubin concentration

The level of Bilirubin concentration was taken in preparation of the administration of chemotherapy in weeks 10, 73 and 146. The values were normal. The levels of Bilirubin concentration decreased to values below normal in week 55. During the second and third courses of chemotherapy the levels of Bilirubin concentration remained stable within the normal range.
Longitudinal Clinical Summarization Research

• “Integrated Timeline”

Patient and Visit Information

Time axis Adjustment

Vital Signs Records

Orders

ECG Exam

Progressive Notes

Medical Image Exam

Lab Test Results
Longitudinal Clinical Summarization Research

• HARVEST

### Timeline: 8/1/20 to 10/24/20

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Details</th>
</tr>
</thead>
</table>
| Admitted: 6/2/20                           | 6/2/20     | Visit Type: Clinic
| Attending: Dr. Chest Pain NOS              | 6/2/20     |                                                                           |
| Admitted: 9/21/20                           | 9/21/20    | Visit Type: REFERRED AMBULATORY SERVICE
| Attending: Dr. Perforation Gallbladder      | 9/21/20    |                                                                           |
| Admitted: 9/27/20                           | 9/27/20    | Visit Type: Clinic
| Attending: Dr. Acute Diastolic Heart Failure| 9/27/20    |                                                                           |
| Admitted: 10/6/20                           | 10/6/20    | Visit Type: Inpatient
| Attending: Dr. Acute CHF                 | 10/6/20    |                                                                           |

### Stable Angina Pulmonary Hypertension

- Edema
- Volume overload
- Obese
- OSA
- Chest pain
- Hypophosphatemia
- Morbid obesity
- Pruritis
- Weight gain
- Hypertension
- DM2
- LHV
- CHF
- Dyslipidemia
- Abdominal mass
- Scar
- Hyperphosphatemia
- Anasarca
- Angina
- Hypoventilation

### Notes about Dyspnea 8/1/20 - 10/24/20

<table>
<thead>
<tr>
<th>Event</th>
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<th>Time</th>
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<td>Medicine Follow-Up Free Text Note</td>
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<td>4:06 AM</td>
<td></td>
</tr>
<tr>
<td>Nephrology Consult Free Text Note</td>
<td>10/13/20</td>
<td>2:52 PM</td>
<td></td>
</tr>
<tr>
<td>Cardiology Consult Attending Follow-up Free Text Note</td>
<td>10/13/20</td>
<td>11:27 AM</td>
<td></td>
</tr>
<tr>
<td>Cardiology Consult Follow-up Free Text Note</td>
<td>10/12/20</td>
<td>11:40 AM</td>
<td></td>
</tr>
<tr>
<td>Milstein Hospitalist Resident/PA Follow-up Free Text Note</td>
<td>10/12/20</td>
<td>7:02 AM</td>
<td></td>
</tr>
<tr>
<td>Milstein Hospitalist Resident/PA Follow-up Free Text Note</td>
<td>10/11/20</td>
<td>12:43 PM</td>
<td></td>
</tr>
<tr>
<td>Cardiology Consult Free Text Note</td>
<td>10/10/20</td>
<td>10:14 AM</td>
<td></td>
</tr>
<tr>
<td>Medicine Follow-Up Free Text Note</td>
<td>10/10/20</td>
<td>10:10 AM</td>
<td></td>
</tr>
<tr>
<td>Case Manager Plan of Care</td>
<td>10/10/20</td>
<td>5:31 AM</td>
<td></td>
</tr>
<tr>
<td>Milstein Hospitalist Resident/PA Follow-up Free Text Note</td>
<td>10/09/20</td>
<td>7:58 AM</td>
<td></td>
</tr>
<tr>
<td>Milstein Hospitalist Resident/PA Follow-up Free Text Note</td>
<td>10/09/20</td>
<td>7:21 AM</td>
<td></td>
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<tr>
<td>Nursing Adult Admission History</td>
<td>10/07/20</td>
<td>2:24 AM</td>
<td></td>
</tr>
<tr>
<td>Medicine Admission Free Text Note</td>
<td>10/06/20</td>
<td>11:30 PM</td>
<td></td>
</tr>
<tr>
<td>ED Resident/np/Attending Note (Milestone)</td>
<td>10/06/20</td>
<td>3:04 PM</td>
<td></td>
</tr>
</tbody>
</table>

### Cardiology Consult Free Text Note

- **Cardiology Consult**

- **Requested by:** Dr. 
- **Reason:** Fluid overload
- **HPI:** 57 yo woman with a pmhx significant for morbid obesity, HTN, HLD, DM2, CKD (stage V) not on RRT and making urine, CAD s/p mLAD DES in 7/20, and pulmonary HTN (based on RHC on 7/20) who presents with signs and symptoms of fluid overload. Cardiology is being asked to consult for further management.

  In regards to the patient's functional status, the patient lives a sedentary lifestyle and is now on disability. Over the course of the last month, she has had increasing fluid accumulation with a weight gain of over 25 kg, with worsening EF and cardiac function. Prior to 1 month ago, hER T was 2 blocks, but has now decreased to 15 feet limited by SOB and occasionally with CP. Furthermore, she has a 6 pillow orthopaedic that has been stable for 4 years but has had worsened PND this past month. The patient also reports 3 months of intermittent chest pain. She describes the pain as sharp, retrosternal, and located in the center of the chest, lasting 5 minutes with 1-2 episodes per week. These episodes occur at rest, and improved by sitting up and taking an aspirin.

- **PMHx:**
  1. Morbid obesity
  2. HTN
  3. HLD
  4. DM2
Longitudinal Clinical Summarization

*Commercial*

- >3,800 Certified Health IT Products by ONC
  - [https://chpl.healthit.gov/#/search](https://chpl.healthit.gov/#/search)
Longitudinal Clinical Summarization

Commercial

• Which commercial vendors have visual patient summary tools?
Longitudinal Clinical Summarization

Commercial

- Allscripts “Wand” (iOS only)
Longitudinal Clinical Summarization

Commercial

- Allscripts “Juxly timeline”
Longitudinal Clinical Summarization

Commercial

- iSalus Healthcare
Longitudinal Clinical Summarization

Commercial

- PracticeFusion

<table>
<thead>
<tr>
<th>TYPE/SOURCE</th>
<th>DETAILS</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: Check up (Appt time: 2:30 PM) (Arrival time: 9:06 PM)</td>
<td>05/04/2016</td>
</tr>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: Cough (Appt time: 1:00 PM) (Arrival time: 8:43 PM)</td>
<td>05/03/2016</td>
</tr>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: New pt (Appt time: 12:00 PM) (Arrival time: 12:12 AM)</td>
<td>05/02/2016</td>
</tr>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: No chief complaint recorded</td>
<td>04/29/2016</td>
</tr>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: No chief complaint recorded</td>
<td>04/28/2016</td>
</tr>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: No chief complaint recorded</td>
<td>12/30/2015 Signed</td>
</tr>
<tr>
<td>Office Visit Stephanie Provider</td>
<td>SOAP Note CC: No chief complaint recorded</td>
<td>09/28/2015</td>
</tr>
</tbody>
</table>
Longitudinal Clinical Summarization

Commercial

- Coalese (HIE)
Longitudinal Clinical Summarization

Commercial

• IntrinsiQ UroChart EHR
Longitudinal Clinical Summarization

Commercial

• Kainos Evolve Timeline (NHS)
Longitudinal Clinical Summarization

**Commercial**

- Hospital EHRs

Certified Health IT Vendors and Editions Reported by Hospitals Participating in the Medicare EHR Incentive Program, July 2016

Number of Hospitals Reporting Vendors' Certified Technology

- Cerner Corporation: 1,029 (2014), 953 (2011)
- MEDITECH: 1,500 (2014), 1,029 (2011)
- Epic Systems Corporation: 1,500 (2014), 1,029 (2011)
- Evident: 900 (2014), 800 (2011)
- Allscripts: 400 (2014), 359 (2011)
- Onon Health: 115 (2014), 109 (2011)
- Influence Health: 90 (2014), 86 (2011)
- QuadraMed Corporation: 75 (2014), 75 (2011)
- Staywell: 60 (2014), 60 (2011)
- Persivia: 50 (2014), 50 (2011)
- PatientSafe Solutions: 45 (2014), 45 (2011)
- PatientKeeper: 36 (2014), 36 (2011)
- other commercial vendors (n=125): 36 (2014), 401 (2011)

Longitudinal Clinical Summarization

Commercial

• HealthFusion MediTouch (?

• Careexpand (?

• Epic “Accordion” (?

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Longitudinal Clinical Summarization

Limitations

• Limitations of existing “solutions”
Longitudinal Clinical Summarization

*Limitations*

- Narrow clinical scope (ontology-reliant)
- Trade-off:
  - Customization vs dissemination
Longitudinal Clinical Summarization

Limitations

• Database (non-clinical) concept conformity
  • ‘Patient-on-ventilator’ status requires derivation

• Trade-off:
  • Easy-implementation vs excessive “rule” creation/mapping
Longitudinal Clinical Summarization

Limitations

• Usability/Excessive learning curve

• Trade-off:
  • Power vs simplicity
Longitudinal Clinical Summarization

Limitations

• Poor screen real-estate optimization
  • Overuse of text
  • Underuse of abbreviations, color-coding, iconography

• Trade-off:
  • Legibility, ambiguity, color-scheme familiarity
Longitudinal Clinical Summarization

Limitations

- Inadequate zoom scalability
- Trade-off:
  - Perils of “hiding/filtering” information
Longitudinal Clinical Summarization

Limitations

• Too smart
  • Esp. problem-oriented summarization
  • Impossible to map clinical relevance/irrelevance of every test/finding

• Trade-off:
  • Nicely-distilled summary vs clinician wariness about what is/not displayed
Learning Objectives

1. Learn the importance of clinical information gathering habits among clinicians
2. Enumerate the difficulties faced by clinicians performing electronic health record review
3. Review methods for clinically-oriented organization and prioritization of EHR meta-data
4. Appraise a novel critical care information display system
Longitudinal Clinical Summarization

• Goal:
  • Tell the clinical story through visual summary
  • Focus: Unfamiliar/new ICU patients
Longitudinal Clinical Summarization

• Questions raised for design consideration
1. How long do clinicians spend performing electronic chart review for new patients?

2. What information is reviewed and the average relative utility of different information?

3. How is the information accessed (workflow)?

4. What is the preferred display format for the information?
How much data?
How much data?

<table>
<thead>
<tr>
<th>Health History Element</th>
<th>Mean (SD*)</th>
<th>Median (IQR**)</th>
<th>Top 90th %</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of prior hospital admissions</td>
<td>4.1 (4.7)</td>
<td>3 (1-5)</td>
<td>9</td>
<td>1-60</td>
</tr>
<tr>
<td>Number of prior ICU admissions</td>
<td>2.2 (2.2)</td>
<td>1 (1-2)</td>
<td>4</td>
<td>1-59</td>
</tr>
<tr>
<td>Radiology reports</td>
<td>15 (27)</td>
<td>7 (3-16)</td>
<td>35</td>
<td>0-807</td>
</tr>
<tr>
<td>Clinical notes</td>
<td>525 (766)</td>
<td>324 (58-696)</td>
<td>1289</td>
<td>1-20558</td>
</tr>
<tr>
<td>Major OR†-based procedures</td>
<td>5.3 (8.9)</td>
<td>3 (1-6)</td>
<td>12</td>
<td>0-415</td>
</tr>
</tbody>
</table>

Number of key lifetime elements per patient that a health history timeline would include during an ICU readmission (n = 13,074 patients)

* Standard deviation, ** Inter-quartile range, † Operating-room
ICU Chart Review Habits Study
ICU Chart Review Habits Study

ICU Chart Review Study - Hypothesis

• ICU clinicians spend time and effort performing electronic chart review on new ICU patients, but their specific behaviors, methods, and historical information needs are unclear.
ICU Chart Review Study - Aims

1. Quantify the time providers spend

2. Assess the type and amount of historical data sought during electronic chart review
ICU Chart Review Study - Aims

3. Assess the workflow patterns used within the EHR to complete a chart review

4. Elicit information-display preferences
ICU Chart Review Behaviors, Needs and Preferences Survey

The following questions refer to your electronic chart review behaviors/preferences when considering a new patient being admitted under your care in the medical or medical/surgical ICU. For the purposes of this survey, “electronic chart review” refers to the general review of a patient’s historical clinical data in the electronic health record (EHR).

This survey contains approximately 30 core questions spread among the following categories: General Behaviors, Type of Information Sought, Chart Review Workflow, Information Display Preferences, and Demographic Information. You are requested (but not required) to complete all of the questions. For each section you will have the opportunity to provide free-text input. This survey should not take more than 10 minutes of your time and your response is greatly appreciated. Responses are anonymous, unless you voluntarily provide your email for future study inclusion.


Page 1 of 8

GENERAL BEHAVIORS

Aside from reviewing the immediate ICU admission data (most recent vitals imaging/labs), do you perform any form of historical electronic "chart review"?

- Yes
- No

Next Page >>

Save & Return Later
ICU Chart Review Study - Survey

- 30 core questions (84 total elements) pertaining to a “new medical ICU admission”

- 3-sites surveyed: RST, FL, AZ (247 recipients)

- Consultants, Fellows, NP-PAs, residents (AZ/FL)
ICU Chart Review Study - Survey

Self-reported Duration of Electronic Chart Review for New Medical ICU Patients, Grouped by Team Role (n=153)
ICU Chart Review Study - Survey

Self-reported Historical Depth of Electronic Chart Review for New Medical ICU Patients (n=155)
### ICU Chart Review Study - Survey

<table>
<thead>
<tr>
<th>General Data Categories</th>
<th>Usefulness of Data</th>
<th>Time Spent Reviewing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never</td>
<td>Rarely</td>
</tr>
<tr>
<td>Imaging</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Laboratory Studies</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Diagnostic Studies*</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Microbiology Reports</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Clinical Notes</td>
<td>1%</td>
<td>1%</td>
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<tr>
<td>Medications</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>Vital Sign Data</td>
<td>1%</td>
<td>13%</td>
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<tr>
<td>Pathology Reports</td>
<td>0%</td>
<td>6%</td>
</tr>
<tr>
<td>Allergies</td>
<td>3%</td>
<td>23%</td>
</tr>
<tr>
<td>Surgical/Procedure Reports</td>
<td>1%</td>
<td>7%</td>
</tr>
<tr>
<td>Intake/output Data</td>
<td>2%</td>
<td>15%</td>
</tr>
<tr>
<td>Other Data*</td>
<td>2%</td>
<td>18%</td>
</tr>
</tbody>
</table>

### Clinical Notes Subset

<table>
<thead>
<tr>
<th>Clinical Notes Subset</th>
<th>Usefulness of Data</th>
<th>Time Spent Reviewing Data</th>
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<tbody>
<tr>
<td></td>
<td>Never</td>
<td>Rarely</td>
</tr>
<tr>
<td>New Inpatient Consultation Notes</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>Hospital/ICU Admission Notes</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Hospital Discharge Summaries</td>
<td>3%</td>
<td>10%</td>
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<tr>
<td>Hospital Transfer Notes</td>
<td>3%</td>
<td>15%</td>
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<tr>
<td>Consultation Progress Notes</td>
<td>0%</td>
<td>14%</td>
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<tr>
<td>Primary Service Progress Notes</td>
<td>1%</td>
<td>11%</td>
</tr>
<tr>
<td>Specialty Outpatient Visit Notes</td>
<td>1%</td>
<td>13%</td>
</tr>
<tr>
<td>Emergency Medicine Notes</td>
<td>7%</td>
<td>28%</td>
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<tr>
<td>Primary Care Visit Notes</td>
<td>2%</td>
<td>22%</td>
</tr>
<tr>
<td>Miscellaneous/Test-result Notes</td>
<td>10%</td>
<td>46%</td>
</tr>
<tr>
<td>Nursing Notes</td>
<td>18%</td>
<td>45%</td>
</tr>
</tbody>
</table>

Perceived Usefulness and Time Spent Reviewing Electronic Information for New Medical ICU Patients (n=155)
ICU Chart Review Study - Survey

- 49% report “haphazard/disorganized” workflow

- Clinical Notes most common initial data reviewed

- 77% ‘worry’ about overlooking important data
  - Volume of data (74%)
  - Display/organization issues (63%)
ICU Chart Review Study - Survey

• Potential solutions endorsed:
  • Chronologic order of multi-modal data
  • Color-coding
  • Meta-data parsimony
  • Explicit data filtering
  • “Flagging” of abnormal results (unstructured)
  • Info display customization
Longitudinal Clinical Summarization

• Putting it together – a new tool
Longitudinal Clinical Summarization

- Requirements:
  - Use chronologic ordering (timeline)
  - Scrolling/clicking/tabbing is the enemy
  - Filter display to reduce info overload
    - Based on zoom-level
    - If you filter data, describe it
Longitudinal Clinical Summarization

• Requirements:
  • Limit text
    • Story can be seen without reading
  • Use colors/icons/abbreviations meaningfully
    • Provide on-screen legends
  • Use a “clinical event” mindset
    • not a DB dump
MeRLin

(Meical Record timeLine)

• Interactive, scalable timeline of pertinent historical EHR information for ICU clinicians
• Filters, aggregates, summarizes major events
MeRLin – Prototype Survey

• 21/21: “potentially useful in clinical practice”

• “to correlate interventions, diagnoses with clinical presentation.”

• “is simply a better way to display clinical data over time than [the] current list view displayed by [Mayo’s EMR] and most other EMRs.”
MeRLin – concept
DEMOGRAPHIC INFORMATION
Clinic Number: 0-000-000
Patient Name: Mr. Patient Demo, Age: 59 Y, Birthdate: 01-Jan-1955 Sex: M
Mayo Clinic Hospital - Rochester, Saint Marys Campus - Hospital Summary
Admission Date: 25-Mar-2014 Dismissal Date: 9-Apr-2014
Dismissing Consultant: Henry Q. Johnson, MD
Service: MED2 Type/Desc: SUM

FINAL PRIMARY DIAGNOSIS
#1 Septic shock from impacted kidney stone

ADDITIONAL DIAGNOSES
#2 E. coli bacteremia
#3 S/p tracheostomy for recurrent hypoxic respiratory failure (4/3/2014)
#4 AKI requiring hemodialysis
#5 Acute on chronic LV systolic heart failure
#6 Left leg swelling, initial concern for necrotizing fasciitis, ruled out
#7 Mildly enlarged right lower lobe pulmonary nodule
#8 Obstructive sleep apnea, newly started on CPAP

BRIEF HOSPITAL COURSE
Mr. Demo Patient is a 59 year-old gentleman with history of pulmonary nodule, chronic LV systolic failure, who was admitted to the medical intensive care unit via the emergency department after being evaluated for high abdominal/flank pain. CT chest-PE study was performed to rule out pulmonary embolism given new dyspnea and hypoxia on presentation, and actually identified an obstructing L renal stone. Urology was consulted and was managed medically. Unfortunately, he required admission to the MICU for management of septic shock (fevers, white count, dirty UA), eventually growing pan-sensitive E. coli in 4/4 blood culture bottles. He required intubation and mechanical ventilation for several days due to his shock state and hypoxia, felt due to acute on chronic systolic heart failure and possibly ARDS. Although initially improving and transferred to the floor, he required return to the ICU for BPAP therapy and given a high suspicion for recurrence, had a tracheostomy placed on hospital day 10. With his shock state he did require initiation of CRRT followed by hemodialysis. Cardiology saw him to evaluate for elevated troponins drawn at admission but this was felt to be consistent with critical illness rather than acute coronary syndrome and no medication changes were made. He was dismissed on hospital day 15 to a skilled nursing facility for strengthening and new tracheostomy cares, with follow-up scheduled in Pulmonary, Nephrology, Cardiology, and Urology.

DISMISSAL MEDICATIONS
NEW MEDICATIONS
Lasix 40 mg 1 tablet by mouth once daily.

CONTINUED MEDICATIONS
Aspirin 81 mg 1 tablet by mouth once daily.
Carvedilol 12.5 mg 1 tablet by mouth twice daily.
MeRLin – Data Model

- >120 defined data elements
- 57 department codes with color schema
- 4 main clinical data groups + subgroups

<table>
<thead>
<tr>
<th>Data Element Name</th>
<th>Data Group</th>
<th>Data Subgroup</th>
<th>Display Mnemonic</th>
<th>Display Name</th>
<th>Context (Hover) Box Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiogram</td>
<td>Diagnostic Studies</td>
<td>Cardiology</td>
<td>ECG</td>
<td>ECG</td>
<td>[Display Name] in [Date] in [Author] in [Date] tracing rpc Note/report display</td>
</tr>
<tr>
<td>Cardiac Event/Holter Monitor</td>
<td>Diagnostic Studies</td>
<td>Cardiology</td>
<td>HOLTER</td>
<td>Cardiac Event/Holter Monitor</td>
<td>[Display Name] in [Author] in [Date] Note/report display</td>
</tr>
<tr>
<td>Echocardiogram - Transthoracic</td>
<td>Diagnostic Studies</td>
<td>Cardiology</td>
<td>TTE</td>
<td>Transthoracic Echocardiogram</td>
<td>[Display Name] in [Author] in [Date] Note/report display</td>
</tr>
<tr>
<td>Echocardiogram - Transesophageal</td>
<td>Diagnostic Studies</td>
<td>Cardiology</td>
<td>TEE</td>
<td>Transesophageal Echocardiography</td>
<td>[Display Name] in [Author] in [Date] Note/report display</td>
</tr>
<tr>
<td>Echocardiographic Stress Test</td>
<td>Diagnostic Studies</td>
<td>Cardiology</td>
<td>EchoStress</td>
<td>[testName]</td>
<td>[Display Name] in [Author] in [Date] Note/report display</td>
</tr>
</tbody>
</table>

- Groups/subgroups determined by relative frequency within Mayo ICU patients
MeRLin – Novel Elements

• “Interventions” – things we do to patients
  • Start/stop meds
  • Give fluid/blood
  • Organ support (dialysis, ventilation)
  • Procedures (minor + major)
MeRLin – Architecture

- Web-based platform
  - Desktop + mobile interoperability
- Server-side = Lucee 5 (ColdFusion derivative)
- Client-side = JavaScript, jQuery, Highcharts
- Data model: JSON
  - intended FHIR compatibility
MeRLin – alpha build
MeRLin – Next Steps

• Ongoing development…. (delayed)
• Deployment & debugging
• Case-based head-to-head testing
  • Usability
  • Efficacy (time)
  • Cognitive load (NASA-TLX)
Summary

• EHR review is an important and time-consuming clinical task

• Goals and workflow of electronic chart review are varied
Summary

• Designing effective longitudinal visualization systems is hard, but there is precedent
  • Gold standard evaluation?

• Clinician-oriented systems like MeRLin will be the future
  • Institution/payer-alignment
Comments/Questions/Suggestions?

Thank you!

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Herasevich.Vitaly@mayo.edu