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Analyzing Operative Note Structure in Development of a Section Header Resource

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Abstract

Operative notes contain essential details of surgical procedures and are an important form of clinical documentation. Sections within operative notes segment provide high level note structure. We evaluated the HL7 Implementation Guide for Clinical Document Architecture Release 2.0 Operative Note Draft Standard for Trial Use (HL7-ON DSTU) Release 1 as well as Logical Observation Identifiers Names and Codes (LOINC®) section names on 384 unique section headers from 362,311 operative notes. Overall, HL7-ON DSTU alone and HL7-ON DSTU with LOINC® section headers covered 66% and 79% of sections headers (93% and 98% of header instances), respectively. Section headers contained large numbers of synonyms, formatting variation, and variation of word forms, as well as smaller numbers of compound sections and issues with mismatches in header granularity. Robust operative note section mapping is important for clinical note interoperability and effective use of operative notes by natural language processing systems. The resulting operative note section resource is made publicly available.

Keywords:

Surgical Procedures, Operative; Vocabulary, Controlled; Medical History Taking/methods; Quality and Safety; Documentation; Electronic Health Records

Introduction

Operative notes are traditionally created at the completion of a surgical procedure by the primary surgeon who recalls the procedure details and dictates these into a narrative that is subsequently transcribed. Effective operative note documentation is important for assessing surgical quality (1), billing and medico-legal issues (2, 3), and other secondary uses of operative notes (4). With increasing adoption of electronic health record (EHR) systems, operative notes and other clinical documents are increasingly generated and immediately available. EHR systems also enable other mechanisms for note generation, including voice to text software, typed notes, synoptic reporting, and templated notes.

Synoptic reports are used to create documents with discrete data fields whereby desired information from the note can be collected, stored, and retrieved in a standardized fashion. In contrast, templated notes range in the amount of structure that they contain, including some having highly prescriptive and structured formats to others having mostly free-text narrative with primarily document section structure alone. While dictation and transcription remains the most common mechanism for operative note creation, synoptic reports and templates are increasingly used in surgery for operative report creation and appear to encourage improved completeness of these documents (5, 6). Independent of the mechanism used to create the document, section headers in operative notes provide high level structure and serve as "containers" which provide context to the text within the given section (7).

Previous research has examined section headers in clinical notes, with some work exploring the task of automated classification of sections in documents. As an initiative with the OpenGALEN project, Mori et al. utilized "tags" in 5 clusters (Nature, Safety Context, Interpretation, Intention, and Organization) and evaluated this approach to classify 600 section headings (7). Denny et al. reported on a terminology of document sections in "history and physical" (H&P) notes and developed an associated section terminology with Logical Observation Identifiers Names and Codes (LOINC®) mappings (8). These authors later developed an algorithm, "SecTag", to identify and label section headers and section boundaries in H&P notes. Similarly, others have utilized predefined sections to aid in a number of natural language processing tasks, such as problem list extraction and named entity recognition (9-11).

In the United States, H&P note formats are largely governed by Evaluation and Management (E/M) documentation, which provides guidelines for assessing adequacy of documentation for each patient encounter resulting in a "level of service" and justification for a patient bill (12). Operative notes, in contrast, are not covered by E/M, and the Joint Commission (13) and Centers for Medicare & Medicaid Services (CMS) (14) have specified criteria for operative notes including information on suggested contents and note sections. Overall, Joint Commission designates eleven required elements for operative notes: name(s) of primary surgeon/ physician and assistants, pre-operative diagnosis, post-operative diagnosis, name of the procedure performed, findings of the procedure, specimens removed, estimated blood loss, date and time recorded, indications for the procedure, intra-operative complications, and a full description of the procedure.

The Health Level 7 (HL7) Structured Documents Workgroup seeks to develop structured healthcare document standards to promote document and data interoperability. This group has created implementation guides for clinical documents including one for operative notes, the Implementation Guide for HL7 Clinical Document Architecture (CDA) Release 2.0, Operative Note Draft Standard for Trial Use Release 1 (HL7-ON DSTU) (15). This specification includes Level 1 (header constraints), Level 2 (section level constraints of the structuredBody of the ClinicalDocument), and Level 3 (entry level constraints within a section; specifying only the Plan section of Operative Notes) requirements. The HL7-ON DSTU was created using a variety of data sources and expert opinions including subject matter expert input, summary statistics from sample operative notes, Joint Commission Operative Note Requirements: Standard IM.6.30 (13), and CMS Operative Note Requirements (14). Where possible, the HL7-ON DSTU utilizes existing clinical statement entries and Continuity of Care Document (CCD) elements, and other Implementation Guide templates. As such, some items considered clinical statement entries in other contexts are treated as sections. The HL7-ON DSTU also maps section headings using LOINC® where available.

To improve available resources and tools for clinical natural language processing[1] specifically for operative reports (16, 17) and using our experience with clinical standards evaluation (18-20), we sought to use the HL7-ON DSTU and LOINC® section codes to represent operative note section headers and to develop a resource for operative note section headers.

Materials and Methods

Study Overview

Figure 1 provides a high level summary of this study. The HL7-ON DSTU was examined and section headers with associated LOINC® codes were collected along with potential document section headers from LOINC®. In this case, LOINC® was used as the clinical terminology for mapping section headers, which are considered an observation or measurement. Although the Systematized Nomenclature of Medicine--Clinical Terms (SNOMED CT) contains many clinical concepts, section headers and document names are not represented. All operative notes over a 4-year period from University of Minnesota-affiliated Fairview Health Services, which includes an academic medical center, one children's hospital, four community hospitals, and three ambulatory surgery centers, were collected from a full range of general surgery and surgical subspecialties, and section headers were extracted. Headers were mapped and coded to eliminate non-section headers, assess section header variation, and identify granularity issues with mapping to structured sections. The section headers and mappings were combined into a resource. Institutional review board approval was obtained and informed consent waived for this minimal risk study.

HL7-ON DSTU Section Header Extraction

Level 1 and Level 2 HL7-ON DSTU constraints were used in this evaluation. Level 1 header elements included information commonly contained in sections for operative notes (e.g., "Primary Performer" - typically referred to as the "Surgeon" or "Primary Surgeon" in operative notes is a header element). Required and optional operative note section names were used along with LOINC® section mappings, section descriptions and suggested information about each item. Level 3 constraints were excluded from the analysis as were Level 1 header elements not related to section headers (such as elements to encode the overall operative note specification).

In addition to the HL7-ON DSTU section headers, LOINC® section header names, codes, and descriptions were collected by extracting entries of "DOCUMENT_SECTION", resulting in 121 distinct sections from LOINC® Version 2.42. Unmapped terms with this list were also mapped to "CLASS" entries of "H&P.HX", "H&P.HX.LAB", "H&P.PX", or "H&P.SURG PROC" with free text search in a second step.

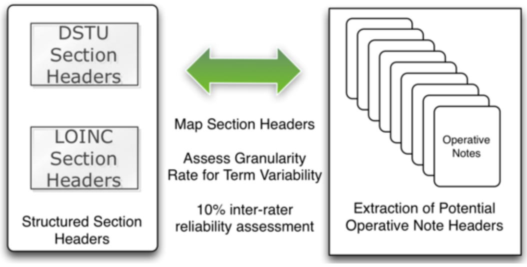

Figure 1 – Overview of Study

Operative Note Section Header Evaluation

Potential operative note section headers were automatically extracted using heuristic rules including the use of capitalization, semi-colons and hyphens, and line-breaks. Frequencies of each potential header were calculated and a cut-off of 100 was used in coding headers. The eliminated set of headers accounted for less than 2% of overall entries.

Each header was then manually designated as a document title, a potential section header, or not a potential section header by two coders. Potential section headers were then mapped to a HL7-ON DSTU standard section name and the provided LOINC® section specification, if available. Table 1 provides an overview and examples of section header codings.

Table 1 – Coding for Operative Note Section Headers

Coding and Explanation	Example(s)
Not a Section Header: *term is not a known section header or document title*	"See Radiology Report From"; "Operating Room"
Document Title: *term is a document title*	"Brief Operative Note"; "Operative Report"
Document Header Information: *term is other document information*	"Patient Identification"; "Dept"
Correct Section Header: *term is preferred section in* HL7-ON DSTU	"Anesthesia"; "Complications"; "Surgery Description"
New Section Header: *term not in* HL7-ON DSTU	"Cross-Clamp Time"; "Preoperative History"
Synonym: *term is alternate synonymous section name (new or known section)*	"Surgery Description" (*Preferred*) vs. "Operation Description"
White-Space, Formatting, Misspelling: *white-space, formatting, or misspelling*	"Post-operative" vs. "Postoperative"
Word Form Variant: *term is word form variant to preferred or synonym term*	"Preoperative Diagnosis" vs. "Preoperative Diagnoses"
Abbreviation: *term is an abbreviation*	"EBL" vs. "Estimated Blood Loss"
Compound Section Header: *two or more sections designated*	"Operative Indications and Consent"

[1] http://healthinformatics.umn.edu/research/nlpie-group

Same Granularity: *term has same granularity as mapped header*	"Specimens" vs. "Specimens Removed"
Less Granularity: *term has less granularity than mapped header*	"Diagnoses" vs. "Postoperative Diagnosis" or "Preoperative Diagnosis"
More Granularity: *term has more granularity than mapped header*	"Arthroscopic Findings" vs. "Findings"

Each extracted potential section header name was then coded to designate if the header was: the preferred section header name; a new section header from the HL7-ON DSTU; a synonym; had white space, misspelling, or formatting variation; a word form variant; an abbreviation; a compound section header; or a header with additional granularity compared to the HL7-ON DSTU suggested section header specifications. Mapped entries were compared to the section name and coded according to their granularity as: equal, greater, or less granularity. Finally, if a section header could not be mapped to the HL7-ON DSTU, the section header was mapped to LOINC® (21).

Approximately 10% of all mappings were evaluated by both coders (a surgeon and informatician (GM) and a surgeon and informatics graduate student (EA)) in order to assess inter-rater agreement. Percent agreement and Kappa were calculated for mappings to document titles, non-section headers, and section headers; coding for HL7-ON DSTU section headers; and assessment for entry variation (e.g., word forms and synonyms).

The section headers and subsequent mappings were used to create a resource of operative note section headers to improve the reuse of these notes. The resource contains section header terms, term mapping to HL7-ON DSTU and LOINC, and information granularity of mappings.

Results

HL7-ON DSTU Section Header Extraction

Operative note section names and LOINC® section mappings for all designated sections in the HL7-ON DSTU were collected. This included 3 main header elements related to operative note sections which resolved to 6 potential section elements, 12 section names (8 required), and 4 subsection names (all options). Table 2 contains example entries for these 18 elements from the HL7-ON DSTU.

Table 2 –Operative Note Sections from HL7-ON DSTU

Section	LOINC Code	Component Name
Consent (O, H)	N/A	CONSENT FOR SURGICAL PROCEDURE
Anesthesia (R, Sec)	8724-7	SURGICAL OPERATION NOTE ANESTHESIA
Indications (O, Sec)	10217-8	SURGICAL OPERATION NOTE INDICATIONS
Implants (O, Sub)	55122-6	SURGICAL OPERATION NOTE IMPLANTS

R:required;O:optional;H:header;Sec:Section; Sub:Subsection

Operative Note Section Header Evaluation

Automated extraction of headers from 362,311 operative note section resulted in 2,999,414 entries. Removal of entries with a frequency of less than 100 (n=52,054) resulted in 2,947,360 (98.3%) total entries and 476 unique entries.

Initial coding demonstrated that 8 headers (6,975 instances) were document titles, 7 headers (15,525 instances) were document header information, and 77 headers (26,189 instances) did not represent valid potential section headers (Table 3). Of the remaining 384 section headers (2,898,771 instances), 66% section headers (93% instances) mapped to the DSTM and after including LOINC® sections for the remaining elements, successful mappings were obtained for 79% of headers (98% of instances). We also observed large numbers of synonymous terms, normalized variants and other formatting associated with section headers.

Table 3 – Operative Note Section Header Findings

	Headers N (%)	Instances N (%)
Overall	476 (100)	2,947,360 (100)
Document Title	8 (2)	6,875 (0.2)
Header Information	7 (1)	15,525 (0.5)
Not a Section Header	77 (16)	26,189 (0.9)
Section Header	384 (81)	2,898,771 (98)
Map to HL7-ON DSTU	255 (66)	2,735,563 (93)
Granularity		
Same Granularity	179 (70)	2,132,446 (78)
Greater Granularity	65 (25)	594,605 (22)
Less Granularity	11 (4)	8,512 (0.3)
Variation in Terms		
Normalized Word Form	63 (25)	328,090 (12)
Formatting Variation	18 (7)	318,233 (12)
Synonyms	177 (69)	1,203,053 (44)
Abbreviation	18 (7)	256,103 (9)
Map to HL7-ON DSTU or LOINC®	304 (79)	2,833,094 (98)
Mapping Failure	80 (21)	65,677 (2)
Multiple Sections	22 (28)	10,607 (16)
No Mapping	58 (72)	55,070 (84)

Table 4 summarizes mappings to the HL7-ON DSTU including numbers of terms mapping to different headers and the proportion of terms that mapped with equal granularity. There was significant variability in expression for many HL7-ON DSTU section headers, and differences in granularity particularly for section headers for primary performer and secondary performer. An analysis of the 30 most common section terms mapped to the HL7-ON DSTU in all but one case, and the remaining header was a LOINC® section mapping (data not pictured).

Table 4 – HL7-ON DSTU Section Header Mappings

Total Headers	Unique Headers	Section Name	Same Granu-larity
211,303	4	Anesthesia	99.8%
93,408	6	Complications	100%
16,898	10	Disposition	58.5%
115,307	5	Estimated Blood Loss	100%
2,945	7	Implants	100%
197,127	20	Indications	100%
18,192	20	Operative Note Fluids	79.9%
565,596	33	Operative Note Surgical Proce-dure	100%
22948	11	Plan	88.8%
283	1	Planned Procedure	100%
327,151	13	Postoperative Diagnosis	100%
333,307	14	Preoperative Diagnosis	99.7%
203,494	21	Primary Performer	0%*
383,174	31	Secondary Performer	0%*
32,530	15	Specimens Removed	99.6%
100,374	28	Surgery Description	100%
1,100	2	Surgical Consent	100%
22,208	2	Surgical Drains	100%
86,415	11	Surgical Operation Note Find-ings	99.5%
484	2	Surgical Date of Procedure	100%
1319	2	Surgical Procedure Duration	100%

In the overlap coding of 50 entries, percent agreement and Kappa for the initial mapping of document titles, non-section headers, and section headers was 100% and 1.00; the HL7-ON DSTU mapping agreement for section headers mapping was 92% and 0.94, respectively.

A number of section headers did not map to the HL7-ON DSTU or LOINC® section headers. A number of these appeared to be unique to operative notes such as “Tourniquet Time”, “Sponge and Needle Counts”, “Bypass Time”, “Preoperative Antibiotics”, and “Preoperative Status”.

Discussion

As the demand for the extraction of meaningful information from more challenging clinical data sources such as clinical texts becomes an area of greater focus, operative notes and other clinical documents will be reused for a variety of purposes. These efforts aid quality improvement, research, and ultimately clinical data interoperability. This study examines a structured document standard for operative notes, which includes Level 1 (Header) and Level 2 (Section) specifications. Section headers from the HL7-ON DSTU and additional LOINC® sections headers were evaluated on headers extracted from a large number of operative notes from an integrated healthcare delivery system. The standards covered most header instances although amongst unique headers, about 20% did not map. We also observed a large amount of variation in the section header term expression including many synonyms, formatting variations, variation in word forms, and compound section headers within the corpus. Although the large variability of expressions in section headers was not altogether, unexpectedly due to the known variety of expressions commonly seen in clinical text, this was an interesting observation in that the overall section header number was large even for headers, which are generally considered semi-structured and more constrained.

While the HL7-ON DSTU provides eight required section names and a small number of main header items that are conventionally sections in operative notes, our study demonstrates the wide variability in expressions of these elements, the frequent use of optional sections, including the 8 section/subsection elements designated in the HL7-ON DSTU as well as 49 section headers designated in LOINC® and not in the HL7-ON DSTU and 58 section headers unique to both the HL7-ON DSTU and LOINC®. As the HL7-ON DSTU authors note, the base specification for an operative note, like other clinical documents, is the HL7 CDA, Release 2.0, allowing for other sections not present in the HL7-ON DSTU to occur in operative notes. Further, despite the significant challenges with variability in expression of section headers present in our corpus, the “exact text of the section names are not mandated” by the HL7-ON DSTU.

Several of the unique sections that did not map to the HL7-ON DSTU or LOINC®, including “Tourniquet Time”, “Sponge and Needle Counts”, “Bypass Time”, “Preoperative Antibiotics”, and “Preoperative Status” may be valid optional section headers. Some of these are important elements for operative notes for certain subspecialties (e.g., cardiac surgery, transplant surgery, or vascular surgery). Further assessment of operative note sections in other hospital systems may also be helpful for establishing the generalizability of the results of our study.

We also observed issues with respect to both granularity as well as variability in expressing different section headers. In particular, the section header “Disposition” which is standard to the HL7-ON DSTU had a number of entries that were more granular than the general header, including “Postoperative Condition” or “Prognosis”. Similarly, both “Primary Performer” and “Secondary Performer” had wide amounts of variability to the amount of detail expressed. “Primary Performer” included more granular terms such as “Attending Neurosurgeon” and less granular terms such as “Physician”, which is under specified enough that it is unclear whether this represents a Primary Performer or not. Similarly, “Secondary Performer” had mostly more granular terms, many of which were trainees including residents and fellows, as well as the designation of assistants and other providers involved with procedures.

With respect to variability in section header expression, many terms including “Operative Note Surgical Procedure” and “Surgery Description” had many terms to express the same section header. This was similarly the case with “Primary Performer” and “Secondary Performer”, as just described. Surprisingly, sections like “Indications” and “Operative Note Fluids” also had wide variability with 20 different section terms for these two section headers each. We observed that while “Operative Note Fluids” is the section recommended for operative notes, surgeons were sometimes to describe the more significant resuscitative elements like blood products and colloid administration and instead used ad hoc section headers like "Components Used".

While the majority of the section headers were fully specified by their name, there were some section headers where the content of the associated section was ambiguous. For instance, the section header "Procedure" or "Procedure(s)" in most cases designates "Operative Note Surgical Procedure", which lists the procedure(s) performed by the surgeon, similar to the "Surgical Procedure" (Header) which provides coded enumeration of the procedures performed. However, in some cases, the section "Procedure" can be the section most commonly labeled with the operative note section "Surgery Description", which described the procedure in detail. The disambiguation of these headers may be addressed in future studies at the semantic level with the contents of operative notes using machine-learning or other automated approaches. This also points out the large amount of variability in expression and practice with operative note composition.

There are several limitations to this study. Section headers were extracted from operative notes using a set of deterministic section segmenting rules, and some were likely missing in our analysis. Additionally, while comprehensive in sample size and having data created from academic and community sites, the study was conducted within a single regional hospital system composed of six hospitals including an academic hospital, a children's hospital, four community hospitals, and three ambulatory surgical centers. The study's findings could be further validated in a future corroborating study.

Conclusion

Structured document standards and well-formed section header designations are important for interoperability of clinical documents and natural language processing systems that consume these documents. We evaluated the HL7-ON DSTU specification for operative note section headers and LOINC®. Our findings confirm that most section headers are covered by the HL7-ON DSTU and LOINC®. However, there is a large amount of variability in section header expression, and a number of section headers specific to operative notes not currently present in these resources. These findings should be considered for future HL7-ON DSTU iterations and possibly for addition to LOINC®. The resulting section header resource can also be used for section header mappings for natural language processing systems.

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