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A Protocol Entry Catalog for Intraoperative Neuromonitoring – Steps Towards an Ontology

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Abstract. In neurosurgery, intraoperative neurophysiological monitoring (IOM) with continuous measurements of neural electrical activity may reduce the risk of postoperative deficits. During an IOM, surgical information as well as neurophysiological, surgical and anesthesia events have to be recorded. So far, there is no common standard for this task available. In this paper, such a standardization with the aim of facilitating the data input and making the protocols data available for different sorts of analyses is described. We developed a protocol entry catalog with 200 standard expressions, which were divided into four categories: IOM, surgical procedure, anesthesia and others. An empirical assessment of the catalog by the IOM team showed the need for subcategories. In the final version of the catalog, the standard terms were grouped into 25 subcategories. The catalog is a first step to support systematic research into the occurrence of clinical events during the IOM and their association with postoperative neurological deficits that could enable improved surgical procedures in the future.

Keywords. Intraoperative Neuromonitoring, Intraoperative Neurophysiology, Protocol Entries, Standardized Data, Ontology

1. Introduction

In neurosurgery it is crucial to distinguish healthy brain tissue from pathological tissue. For the eyes of a neurosurgeon functional areas and tracts are not visible. Injuries in such areas lead to the occurrence of postoperative neurological deficits, e.g. motor paralysis. With intraoperative neurophysiological monitoring (IOM) continuous measurements of neural electrical activity during surgery are possible, allowing to reduce the risk of postoperative deficits [1-3].

The IOM team documents patient and surgical information, as well as neurophysiological, surgical and anesthesia events, each event with a time stamp. Further, neurophysiological baseline measurements of different evoked potentials and, later on, amplitude and latency change in the signal measurement values are added. Today, no common standard for the content of IOM protocols exists. This paper describes first steps for such a standardization, relying on the analyses of several IOM protocols, leading to a protocol

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entry catalog. The catalog was developed as part of a web-based information system called “IOM-Manager”, which has been implemented at the Inselspital department of neurosurgery. The IOM-Manager was implemented with the MEVN (MongoDB, Express.js, Vue.js and Node.js) technology stack [4].

Our protocol entry catalog has two goals: to facilitate data input during surgery and to increase the usefulness of the protocol data for later analyses. It can help to answer research questions such as “how are clinical events during IOM associated?” and to implement prediction models using the standardized event data.

2. Methods

The documentation process was analyzed by observing neurosurgical and neurophysiological IOM procedures as well as by examining handwritten protocols at the Inselspital. Based on these protocols, different data input options for digital IOM documentation such as barcode scans, voice input [5] and manual documentation were discussed and the most suitable identified together with the IOM team at the Inselspital. It was decided to use a web form with dropdown menus for selecting event descriptions from a restricted number of possibilities. This required a suitable event catalog.

The event catalog was developed in an iterative fashion. First, the latest 100 paper protocols were reviewed manually, classified based on the main diagnosis of the patients and searched for recurring entries. Then, standard texts and clusters were defined for the recurring entries. In the last step, handling of the catalog was assessed together with the IOM team in order to refine the catalog and provide a final clustering.

3. Results

The IOM unit has collected more than 4000 handwritten protocols so far. Based on the various operations, they use eleven different protocol templates, which however differ only slightly. The protocols contain patient and surgical information. The measured values of the baselines of different evoked potentials are noted in a table at the beginning and towards the end of the surgery.

During the surgery, changes in the amplitude and latency of the measured signal values are continuously monitored and recorded using inomed ISIS IOM System. In addition to that, events related to anesthesia, surgery and further clinical incidents such as signal loss or tumor extirpation are manually recorded together with a time stamp. An entity relationship model (ERM) for this IOM setting is shown in Figure 1.

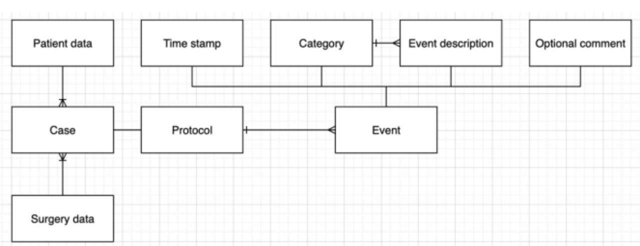

Figure 1. ERM of the catalog and its relationships to the case information. A patient can have one or more IOM cases. Through a protocol, a case will be associated with one or several events. An event consists of a time stamp, a category, an event description and optionally a comment.

The case statistics are kept in a surgical track record (book) and an additional spreadsheet. Signal curves from the medical device, which contain the measured evoked potentials during the surgery, are printed out and added to the paper protocol.

Examining the latest 100 paper protocols for recurring event descriptions led to 200 standard expressions, which we clustered into four categories: IOM, Surgical Procedure, Anesthesia and Others. Under the category IOM, all signal changes in evoked potentials and mapping settings are subsumed. An assessment of the implementation of this first catalog by the IOM team resulted in the requirement for subcategories. The main reason was the realization, that more dropdown menus with less entries in each facilitate documentation. In the final version of the catalog, the standard expressions were clustered into 25 subcategories. Many of the subcategories are taking the modalities, e.g. evoked potentials, into account (see Table 1). In the category surgical procedures, the subcategories were defined on the basis of the diagnoses such as tumor surgery.

Table 1. Part of the final catalog version with the 3 categories IOM SEP (somatosensory evoked potentials), IOM EEG (electroencephalography) and Tumor surgery.

Category	**Event description**
IOM SEP	SEP artifact overlaid
	SEP constant
	SEP drop
	SEP flatter
	SEP fluctuates
	SEP new baselines
	SEP no signal
	SEP reproducible
	SEP slightly delayed
	SEP stable
IOM EEG	EEG burst suppression
	EEG changes
	EEG of higher frequencies
Tumor surgery	Tumor extirpation
	Tumor preparation
	Tumor resection under dynamic Mapping
	Tumor outside
	Tumor visible

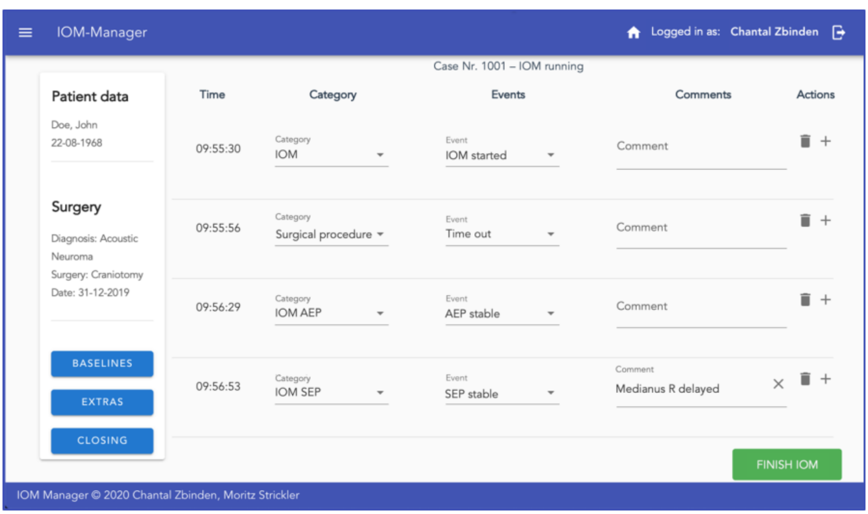

Figure 2. The picture shows how the protocol documentation in our application looks like. On the left is information about the patient and the surgery. Each entry in the protocol contains a time stamp, a category and an event description. Furthermore, a free text comment can optionally be added to each entry.

Figure 2 shows the use of the IOM catalog within the IOM-Manager. A new event can be recorded using the plus button on the right. Selecting the main category allows to select the respective subcategories, permitting rapid selection of the appropriate event description. For each event, optional free text comments can be added. The baseline and closing signal measurement values (such as amplitudes, latencies and stimulation paradigms) can be entered using the BASELINES and CLOSING buttons on the left.

4. Discussion

During the development of the catalog, the need for subcategories was detected after an empirical assessment by the IOM team. There are pros and cons of such an empirical approach. On the one hand, a rapid result can be achieved together with good acceptance by the users. On the other hand, the resulting categories and subcategories may not be well designed, there could be overlaps, and there could be a need for more relationships that an is_a between subcategories and main categories. In addition to that, there is a risk that the protocol entry catalog is not suitable for some desired analysis tasks.

In order to overcome such shortcomings and risks, we will develop an ontology based on the catalog described here. Several authors have devised methods for good ontology development. For example, Gruber [6] describes the development of portable ontologies, whereas Noy and McGuiness provide guidelines for taxonomic work to create an ontology [7].

5. Conclusions

In summary:

- Systematic documentation of IOM events is essential for efficient analyses of events-outcome relations.
- A protocol entry catalog represents a good starting point for the standardization, but a future ontology will increase interoperability among different sites.
- The ontology allows automated reasoning, e.g., for finding new research questions just based on the concept relationships among the present instances.
- Further research should also be directed towards a standard terminology for the events and its impact on the related outcome research.

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