Outpatient Pre-Anesthesia Consultation: Can an Expert System Help ?

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Introduction

Current medical reimbursement realities may limit the time an anesthesiologist can spend assessing complicated patients preoperatively. Third-party payers increasingly demand admission of sick patients for complex operative procedures on the day of surgery. These patients are often evaluated and counseled in outpatient pre-anesthesia consultation clinics several days before surgery by busy, semi-autonomous anesthesia paraprofessionals and trainees uninvolved in their actual operating room care. The efficient and careful evaluation and emotional preparation of such patients is extremely important on medico-legal and humanitarian grounds. An error or omission in the preoperative evaluation may have rapidly disastrous consequences in the operating room. This abstract describes the early development of a robust, computer-based environment (HyperCard-Based Operating Room Anesthesia Consultation Environment or "HORACE") to assist anesthesiology trainees, PAs, and CRNAs in the rapid, correct, thorough, and legible preoperative evaluation of patients presenting at these clinics. HORACE contains two components: 1) an efficient human-computer interface for generating preoperative evaluations, and 2) an integrated expert system for guiding the evaluation and patient consent processes. These components are now described in greater detail.

System Design

The first component is a Macintosh-based easy-to-use interface for recording history and physical examination, composed entirely of menu items and dialog boxes, so that a preoperative can be assembled almost entirely through a sequence of "point-and-click" operations using a mouse. This system features extensive on-line help, available by simply pointing at the menu, button, or box in question using "help balloons" under Mac System 7. Such help includes definitions (e.g., stable vs. unstable angina; or mild, moderate, severe LV dysfunction), and/or the corresponding question asking a patient to derive the information. The resulting menus and dialog boxes are "linked" so that positive responses in the history or physical result in the system user being automatically guided to more-focused questions (e.g., hx of HTN results in questions about prior MI, CVA, renal impairment, CHF Hx, quality of HTN control). A user can ignore the guidance offered him by "exiting" the dialog boxes at any point. As soon as a chain of dialog boxes has been answered, a chunk of text is placed in a HyperCard card, corresponding to the preceding dialog. At the conclusion of the interview, a laser-printed preoperative assessment is produced from these HyperCard cards in a standard preoperative format. Prior preoperative assessments concerning a given patient are available in computer-readable form, to allow updating when the patient arrives for subsequent anesthetic evaluation.

After the initial patient database has been collected using the first component, the database may then be directly used to guide consultation and consent processes that comprise one usual part of an anesthetic consultation. This part is undeniably much more complex. For example, if invasive monitoring will likely be performed on a patient during a procedure, it is useful to communicate this fact to the patient during the preoperative visit and to the team caring for the patient intraoperatively, so that appropriate preparations can be made and to prevent unpleasant surprises in the holding area. A determination that such a procedure is indicated is in part dependent on knowledge about the particular surgical procedure, knowledge about the patient, and knowledge about the general indications for the monitoring procedure. In short, complex decision-making is involved that may be assisted by using an artificial-intelligence-based expert system. Such an expert system, comprising relatively few highly abstract

decision rules and semantic networks composed of frame-like objects, is under active development as the second component of HORACE.

This new expert system will be used to guide patient consent processes for: a) invasive monitoring intraoperatively; b) awake intubation, c) blocks for postoperative pain, d) postoperative mechanical ventilation, and for preoperative consultation (specifically including cardiac, pulmonary, endocrine, and neurologic specialties). The capacity of an expert system to explain its "reasoning" may be utilized to help educate anesthesia residents using the system. Further, reports will be generated for the operating room concerning need for special procedures and resources e.g., pressure transducers, difficult intubation carts. These reports will include the justifications for utilizing each resource.

The prototype human interface, developed using HyperCard and Windowscript is being further enhanced. Five knowledge bases (KBs) composed of frame-like objects and rules for manipulating them, are under development using Nexpert-Object (a commercially available knowledge representation tool). These knowledge bases are as follows:

a. Operative Procedures KB: a reasonably all-inclusive KB incorporating surgical procedures performed along with associated attributes (incision location, operative positioning, anticipated blood loss, anticipated fluid shift magnitudes, anticipated procedure length, anticipated postoperative pain).

b. Anesthetic Procedures KB: Hierarchy of objects such as airway control procedures, monitoring procedures, nerve block procedures with attributes such as indications, complications, contraindications, etc.

c. Anesthetic Modalities KB: GA modalities, Regional Anesthesia Modalities, Combined Modalities, etc. with semantic links into the Anesthetic Procedures KB.

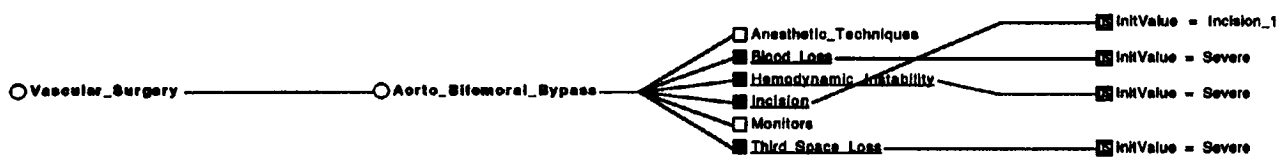
d. Neuro-Anatomical Correlates KB: a KB to relate nerve block with anesthesia, e.g., regions blocked with axillary brachial plexus blockade, anatomic regions blocked with dermatomal blockade in epidural, spinal.

e. Medical Conditions KB: Initially a brief, succinct KB including the most commonly encountered medical conditions of anesthetic interest with semantic links into anesthetic procedures and modalities KBs (when management will be altered) and indications for preoperative consultative referral. KB can be expanded later.

Knowledge Representation in HORACE

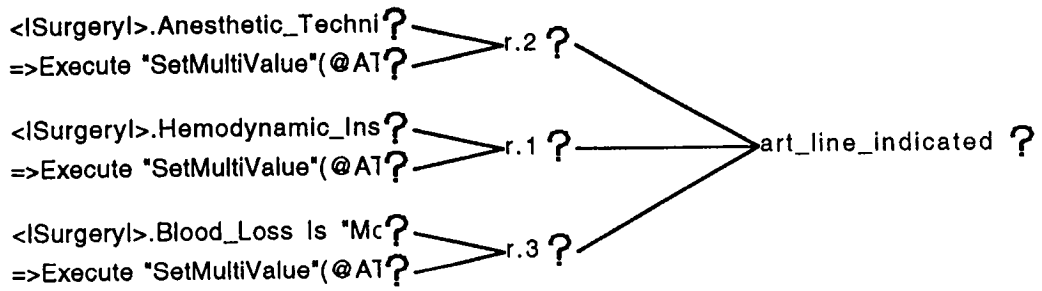
We will now consider certain specific examples of object hierarchies and rules from HORACE's expert system component. In this section, we will consider specifically aorto-bifemoral bypass grafting as an example. This surgical procedure is sufficiently involved and frequently performed on sufficiently sick patients to illustrate the approach being pursued. The following object hierarchy represents a brief expansion about the Aorto_Bifemoral_Bypass class showing expansion to include its generalization (Vascular_Surgery), and its other progeny (slot-expansions of these progeny are not illustrated):

Figure 1



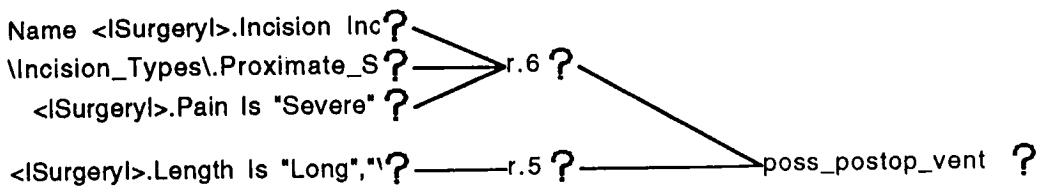
Decisions regarding invasive monitoring are frequently made preoperatively by anesthesiologists considering the medical condition of the patient and the relative stresses imposed by the surgery. Accordingly, knowledge concerning prototypical stresses imposed by the surgery is encoded at the class level. Slots for monitoring and anesthetic techniques are left to be asserted at the instance level. The following rule hierarchy illustrates typical decision making for arterial line placement.

Figure 2



Similarly, knowledge concerning likelihood of postoperative ventilation may be partially encoded using the following rule hierarchy. Also shown is a typical rule from this hierarchy

Figures 3 and 4

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        Rule 6
If
 <|Surgery|>.Incision is assigned to Incision_Types
 And \Incision_Types\.Proximate_Structures is "Diaphragm"
 And <|Surgery|>.Pain is "Severe"
Then poss_postop_vent
 is confirmed.
```

Decision making concerning utility of central neuraxial blockade involves estimates of the pain involved in a procedure, location of that pain, neuro-anatomical correlates, and specific contraindications to a block. The following rule provides an example by which such decision making might be made when combined with the anatomical structures hierarchy shown in the succeeding figure.

Figures 5 and 6

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        Rule 4
If
 <|Surgery|>.Pain is "Severe"
 And <|Surgery|>.Incision is assigned to Incision_Types
 And \Incision_Types\.Start is assigned to Incision_Starts
 And \Incision_Types\.Stops is assigned to Incision_Stops
 And \Incision_Starts\.Neurologic_Correlates is assigned to Incision_Neuro_Structures_Start
 And \Incision_Stops\.Neurologic_Correlates is assigned to Incision_Neuro_Structures_Stop
 And \Incision_Neuro_Structures_Start\.Block_Modalities is "Epidural"
Then Epidural_Indicated
 is confirmed.
 And Execute "SetMultiValue"(@ATOMID=<|Surgery|>.Anesthetic_Modality;@STRING="@ADD=Epidural,@NODUPLICATE,@COMP=STRI
NG";)
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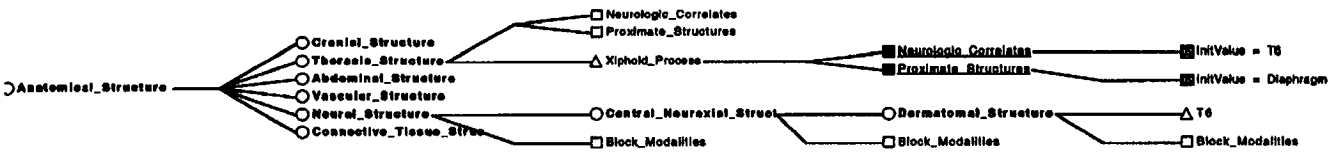

The above figures were all drawn directly from NEXPERT-OBJECT 2.0 B using the HORACE knowledge base.

Potential Benefits

Some potential benefits of HORACE include: 1) automated oversight of junior clinicians where continuous supervision by an attending anesthesiologist is not economically feasible; 2) facilitated construction of a more legible assessment by the user interface (potentially increasing user acceptance of the advice-giving); 3) improved communication of special needs (e.g., invasive monitoring, special airway control techniques) to the operating room.

HORACE in Context

HORACE relates to a number of prior projects in anesthesia and medicine. ATTENDING (1) was an expert system which critiqued anesthetic plans developed by junior anesthesiologists. However, ATTENDING 1) did not emphasize a passive role for the expert system embedded in a larger non-AI development to encourage clinical acceptance, and 2) did not involve itself in the larger issues of intraoperative monitoring, postoperative pain, and postoperative prognostication. Further, ATTENDING was very involved in risk-benefit trade-offs of different anesthetic approaches. HORACE is primarily concerned with prognostication of procedures that may reasonably be employed in a given case. The ultimate choice of procedural mix will be left to the clinician caring for the patient. ONCOCIN (2) was a medical expert system which rendered advice concerning cancer chemotherapy planning in a worksheet form similar to those which clinicians actually use. ONCOCIN asked the clinician a question by unobtrusively placing a question-mark in the work-sheet where information of interest to the expert system should be entered. Thus, ONCOCIN is similar to HORACE in the sense that each has an expert system embedded within and receives information from non-AI data management functions of interest to clinicians.

Current System Status and Future Directions

The data management functionality of HORACE has been developed in crude prototype form. This functionality has not been described extensively in this article. The expert system portion of HORACE is currently under active development. The part of the system relevant to aortic reconstruction has previously been discussed. As can be seen from this realistic example, anesthesiologists typically think in terms of time, space, anatomy, block modalities and other variables when consulting with a patient. This is rather involved reasoning. The pathophysiologic knowledge-base is currently under supervised development by a senior medical student during his elective. The interfaces between the data management functionality and the knowledge-based system have yet to be developed. Initially a unidirectional transfer of information to the expert system in a seamless fashion will be performed. Eventually, interesting questions in intelligent human interface development may be encountered as more direct interaction of the expert system with the clinician is developed. Eventually, the user interface will be used to direct queries from the expert system component.

References:

1) Miller PL. Expert Critiquing Systems: Practice-Based Medical Consultation by Computer. New York: Springer-Verlag.

2) Shortliffe EH, Hubbard SM. *Information systems for Oncology*. In DeVita VT, Hellman S, Rosenberg SA (eds), *Cancer: Principles and Practice of Oncology*. Philadelphia: J.B. Lippincott, 1989, pp 2403-2412