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AJNR Am J Neuroradiol 1986, 7 (1) 155-158
http://www.ajnr.org/content/7/1/155

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The time requirements needed for radiologists to perform intraoperative neurosonography were analyzed. Eighty-five consecutive intracranial and spinal operative procedures were prospectively monitored, and it was found that (1) the average length of time spent in the operating room by the radiologist was 1 hr in spinal cases and 52 min in intracranial cases; (2) the wide range of time spent in each case depended on the complexities of the operation; (3) only one-fifth of the radiologist's time in the operating room was spent performing the study and interpreting the sonograms; and (4) 24% of cases were either emergencies or were performed after normal working hours. It may be helpful to take these factors into consideration when there are plans to offer the service of intraoperative neurosonography.

The usefulness of intraoperative neurosonography (IONS) in many spinal and cranial operations has been well documented. Despite this fact, a widespread implementation of sonographic imaging in the neurosurgical operating room has not occurred. This, we believe, is related to a feeling of uncertainty concerning the time commitment required once a radiology department agrees to provide this imaging service. To compile accurate information addressing the problem of manpower logistics for IONS, we conducted a prospective analysis of the time requirements for IONS procedures. The results of that study are presented here in hopes that this information will provide a foundation on which the decision of whether or not to provide IONS services can, in part, be made.

Subjects and Methods

Eighty-five consecutive IONS procedures performed over a 6½ month period were evaluated by means of a log sheet that was filled out in every case by the attending radiologist. All of the intraoperative sonographic examinations were supervised and interpreted by one of the two authors of this article, each of whom had 24 months prior experience in the interpretation of IONS examinations.

An aide from the sonography section was assigned to each case, and generally that person arrived in the operating room in advance of the radiologist to assure that the equipment was set up properly and that there would be no delays in performing the examination. In every case the radiologist was present whenever sonography was performed. In no cases were the images interpreted by the surgeon alone without the radiologist being in the operating room as an active consultant. The disadvantages of having the surgeon perform and interpret the IONS examination alone have been expressed [1]. The surgeons strove to minimize the radiologist's time in the operating room by requesting his presence no earlier than necessary. All attempts were made by the surgeons to inform the radiologist of the need for IONS well in advance of the surgery.

The following information was obtained on each case: type of examination, whether it was scheduled or nonscheduled, the time the radiologist and aide entered and left the operating room, whether the radiologist was able to leave the operating room during the surgery (i.e., whether the IONS services were rendered in phases), and the time spent in the operating room actually performing and interpreting the sonographic examination. This information was then collated and analyzed.

This article appears in the January/February 1986 issue of *AJNR* and the April 1986 issue of *AJR*.

Received March 26, 1985; accepted after revision June 12, 1985.

Presented at the annual meeting of the American Society of Neuroradiology, New Orleans, February 1985.

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***AJNR* 7:155–158, January/February 1986**
0195–6108/86/0701–0155

Results

Table 1 summarizes part of the data in the major categories of surgical procedures. The procedures are listed in order of their time requirements from the least time-consuming (routine lumbar diskectomy in the spinal category and ventriculoperitoneal shunt in the cranial category) to the most time-consuming (shunting spinal cysts in the spinal category and brain biopsy in the cranial category). The reasons for the wide range of time requirements in each of the categories is addressed in the Discussion.

In addition to the six categories of spinal operations and the three categories of cranial operations, there were five cases of disk removal that were not considered routine or were performed in conjunction with other spinal surgical procedures, five spinal cases termed miscellaneous because they did not fit into any one of the major surgical categories, and four cranial cases also termed miscellaneous because they likewise did not fit into any one of the major surgical categories. These are listed in table 2. Since all of these procedures were so different from one another, they were not tabulated separately in table 1, but the time required to perform each sonographic examination was included in the calculation of the overall time requirement.

When all these procedures were considered together, an average of 60 min of a radiologist's time was required for the spinal cases and 52 min for the cranial cases. In 18 (21%) of the 85 cases there were long enough periods of time during the surgery when sonography was not required so that the radiologist could leave the operating room. In those cases, the average length of time out of the operating room was 48 min.

In most cases the aide arrived in the operating room before the radiologist in order to set-up the equipment and left after the radiologist with the sonographic equipment. As a result, the aide spent on the average seven more minutes in the operating room than did the radiologist. When the sonographic examination was done in phases, the aide left the operating room only when there was other work to be done in the sonography section. The sonographic equipment never left the operating room until the case was completed, even if the examination was done by the radiologist in phases.

While in the operating room, an average of 10 min (17% of our time) in the spinal cases and an average of 11 min (21% of our time) in the cranial cases was spent actually performing and interpreting the sonographic examination.

Of the 85 cases, seven were emergencies and 13 were scheduled cases that either began so late in the day or the procedure took so long that the examination was performed after normal working hours (after 5 P.M.). The seven emergencies were five Harrington rod instrumentations, one lumbar diskectomy, and one ventriculoperitoneal shunt. If the emergency cases are added to those cases in which sonography was performed after hours, nearly one of four cases (20 of 85) fell into this "unpredictable" category.

TABLE 1: **Time Requirements for Intraoperative Neurosonography**

Type of Sonographic Procedure	No. of Patients	Average No. of Minutes of Radiologist's Time (Range): In Operating Room	Average No. of Minutes of Radiologist's Time (Range): Involved in IONS Procedure
Spinal (*n* = 55):			
Routine lumbar diskectomy	4	30 (10–60)	7 (2–10)
Bony decompression for canal stenosis	11	44 (10–100)	7 (5–14)
Bullet removal	5	53 (25–105)	9 (6–15)
Soft-tissue mass resection	10	54 (25–135)	11 (5–28)
Harrington rod instrumentation	9	57 (40–90)	8 (4–15)
Shunting spinal cysts	6	106 (65–160)	22 (16–34)
Complex diskectomy	5	*	*
Miscellaneous	5	*	*
Cranial (*n* = 30):			
Ventriculoperitoneal shunt	9	19 (10–45)	8 (2–10)
Soft-tissue mass resection	11	50 (10–75)	10 (5–20)
Brain biopsy	6	95 (55–105)	17 (10–32)
Miscellaneous	4	*	*

* See Results and table 2.

TABLE 2: **Miscellaneous and Complex Diskectomy Cases**

Procedures (No. of Cases)
Complex diskectomies:
Traumatic disk and pseudomeningocele repair (1)
Multilevel diskectomy (1)
Thoracic diskectomy (1)
Diskectomy plus bony decompression (2)
Miscellaneous spinal:
Posttraumatic spinal cord cyst suspected but only myelomalacia found (1)
Bone fragment removal from canal (1)
Obstructed catheter in spinal cord cyst suspected, but cyst found to be collapsed (1)
Cord imaging prior to dorsal root entry zone laser application (2)
Miscellaneous cranial:
Subdural evacuation and ventriculoperitoneal shunt (1)
Locating, removing, and replacing ventricular catheter (1)
External ventricular drain (1)
Shunting suprasellar subarachnoid cyst (1)

Discussion

Sonographic imaging in the neurosurgical operating room has recently been recognized as having a significant impact on surgical management during various intracranial and spinal procedures. Documenting the proper positioning of ventricular shunt catheters [2, 3], localizing and characterizing intracranial masses [3–10], localizing and characterizing intraspinal masses [11–15], demonstrating the effectiveness of Harrington rod instrumentation [16], guiding the positioning of shunt catheters into intraspinal cysts and confirming their subsequent collapse [17], and identifying the position of intraspinal metallic foreign bodies and assuring the removal of all such fragments [18, 19] are areas where IONS has proved its usefulness. Despite this, radiologists have been reluctant to incorporate this imaging service into their practice, because, in our opinion, they are wary of the time and manpower commitment required of them if IONS services were offered. Our time study substantiates the notion that IONS is a procedure requiring a significant allotment of time, despite reasonable efforts to minimize the radiologist's time in the operating room. Specifically, if all the cases are considered together, an average of 1 hr was spent in the spinal sonographic examinations, whereas an average of 52 min was spent in the intracranial examinations. The sonographic aide spent a slightly longer time in the operating room than did the radiologist.

As would be expected, a wide range of time is spent by the radiologist in the operating room depending on the complexity of the cases or the intraoperative difficulties encountered. In routine lumbar diskectomies, the range of time (10–60 min) depended on whether disk removal was confirmed on the sonographic examination; the necessity of removing a residual, unsuspected disk fragment identified by sonography prolonged the time. Similarly, in bone decompression for canal stenosis, the failure to remove an adequate amount of bone as documented by sonography can require additional surgery and thus prolong the radiologist's time in the operating room to as long as 100 min. In cases of either a diskectomy or bony decompression, the very short times (10 min) shown in table 1 were a consequence of being called to the operating room after the surgeon had successfully removed the disk or decompressed the canal. In those cases, sonography served only to confirm the adequacy of the procedure. Difficulties encountered during removal of bullet fragments included localization and removal of fragments imbedded in dense scar tissue and also discovering unsuspected associated surgically correctable abnormalities such as posttraumatic subarachnoid and intramedullary cysts. This accounted for the prolongation of operating room time up to 105 min in a number of those cases.

The identification, removal, and/or biopsy of soft-tissue masses of the spinal canal and cord caused the length of time to vary considerably depending on the difficulty of the operation. Likewise, in Harrington rod insertions, the time spent in the operating room depended on whether the initial instrumentation adequately decompressed the canal. Monitoring the placement of catheters into intramedullary and subarachnoid cysts with shunting of the cysts into the adjacent subarachnoid space typically was the most time-consuming study (up to 160 min). The necessity of defining the entire configuration of these cysts, including the presence of intracyst septations, and subsequently documenting adequate collapse of the cysts after shunting accounted for the long time spent in the operating room.

Monitoring ventriculoperitoneal shunt placement was usually a rapid study, since passage of the catheter into markedly enlarged ventricles is a simple procedure. Only when the ventricles were mildly enlarged was some difficulty encountered in properly placing the catheter within the ventricular system. In those cases, repeated catheter passage prolonged the sonographic examination up to 45 min. A wide range of time requirements was noted in both those examinations performed during the removal of an intracranial soft-tissue mass and in those cases in which sonography was used to guide the tissue biopsy needle into a brain mass. In the latter type of surgery, localizing a deep lesion was often difficult, but, more often, the extensive time requirements (up to 105 min) were related to the need of waiting for the results of the frozen section and the need to repeat the sonographic guidance of the tissue biopsy needle if the pathologic report was negative.

The time spent in the operating room is most dependent on the length of the surgical procedure itself. We have found that there is very little the radiologist can do to shorten the time required in the operating room. In an effort to minimize this time, however, we left the operating room whenever it was believed that a sufficiently long period of time (at least 20 min) would exist between parts of surgery requiring IONS. Despite this attempt to use our time efficiently, we found that only about one-fifth of our time in the operating room was spent performing and interpreting IONS. This was related to the fact that, although there were gaps of time where IONS was not needed, those periods of time were often not long enough to warrant leaving the operating room. In about one out of five cases, however, we were able to leave and return at a later time. In addition, in our experience the indications for IONS have not changed. It is used frequently for intracranial procedures and is used almost uniformly during spinal surgery.

The sonographic examinations did not significantly prolong the surgical time (see table 1). We believe that it actually had the opposite effect, specifically it decreased the overall surgical time by providing the surgeon an instantaneous and accurate depiction of the progress of his surgery.

Our report indicates that a substantial amount of time is required for proper sonographic imaging in the neurosurgical operating room. Optimum service is provided if one radiologist is assigned to IONS as a priority responsibility each day. In a hospital with a highly active neurosurgical and orthopedic service and particularly one that deals with a significant amount of spinal trauma, emergency IONS must be expected. The existence of these cases and those extending into the evening hours means that the provisions for them must also be made in the daily schedule.

Despite these logistical problems, we believe that the benefits of IONS to the patients' ultimate welfare is so significant that strong consideration should be given to its incorporation into a radiology practice.

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