Technical and Clinical Characteristics of a Surgical Biopsy Probe

William C. Harvey and Jack L. Lancaster

Presbyterian Hospital of Dallas, Dallas, Texas

A probe intended for intraoperative biopsy was designed. It is small, collimated, and separated from the photomultiplier tube and high-voltage source by a flexible fiberoptic light guide. Its use in four patients undergoing bone or soft-tissue biopsies is described.

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The technetium phosphate bone-imaging agents have brought unparalleled sensitivity to the detection of osseous neoplasm and infection. Indeed, this sensitivity is such that frequently bone disease cannot be confirmed by any other diagnostic means, including standard and tomographic radiography. To obtain a firm diagnosis, the clinician often desires to obtain pathological tissue directly by biopsy. Even with external marking devices, biopsy sites are often difficult to identify accurately. The mobility of the skin and the variable thickness of subcutaneous tissue can lead to substantial errors of localization. For these reasons, we designed a miniature gamma scintillation probe, which was manufactured to our specifications by the Harshaw Chemical Corporation, Solon, Ohio. The following requirements were considered: (a) small diameter; (b) collimation with satisfactory sensitivity; (c) light weight; (d) absence of electrical shock hazard; and (e) relatively low cost. We describe here the technical characteristics of this probe and its intraoperative use in four patients undergoing biopsy.

MATERIALS AND METHODS

Technical description. The biopsy probe is novel in that scintillations from a NaI(Tl) crystal, 0.64 × 2.54 cm, are coupled to a photomultiplier tube through a 0.64- × 122-cm, flexible fiberoptic cable. The cable is composed of approximately 6000 fibers, each being 75 μm in diameter. Because of the appreciable light losses in a long fiberoptic cable, a bialkali photomultiplier tube (PMT) with high quantum efficiency was used. Though energy resolution is degraded by the long fiber cable, there is a distinct peak in the pulse-height spectrum, with a peak-to-valley count ratio of 5.7. The full width half maximum (FWHM) of the spectral peak is 63% for Tc-99m. The system's plane-source sensitivity is 87 K cpm/μCi-cm^2 for cobalt-57. The background counting rate was 80 cpm in the Tc-99m window.

Figure 1 shows the structure of the biopsy probe. A 2-mm lead shield running the length of the probe head minimizes response to stray radiation. This shield is especially important when the probe is operating in a body cavity surrounded by radioactivity. The crystal is inset 6 mm from the end of the probe head to restrict the field of view. Table 1 illustrates the FWHM of the line spread function (LSF) for the probe at various distances.

The probe head, flexible fiber cable, and PMT housing are cool gas-sterilized with ethylene oxide before a biopsy. The sterilization requires about 4 hr. The packaged assembly is not placed in an aeration chamber subsequent to gas sterilization. When used in the sterile biopsy environment, a rubber glove finger is placed over the forward tip of the probe head to aid in subsequent cleaning and to prevent possible radioactive contamination. The glove finger is also useful when the procedure involves probing in infected tissue.

To facilitate probing, an audible count-rate indicator was used. This allows the surgeon to probe without losing visual contact with the site. We have constructed an audible count-rate indicator that can produce a signal proportional to a difference in counting rates. In practice,

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For reprints contact: William C. Harvey, MD, Nuclear Medicine Service, Presbyterian Hospital of Dallas, 8200 Walnut Hill Lane, Dallas, TX 75231.

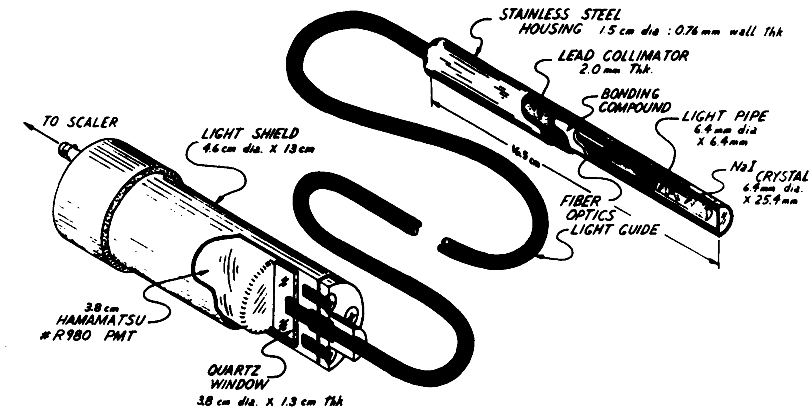

FIG. 1. Mechanical structure of probe.

the probe is first placed over an anatomically representative normal tissue, and this reference level is then set by pressing a single button. All subsequent audible rate "beeps" are an indication of count rates in excess of that seen over the reference point.

CASE REPORTS

Case No. 1. A 55-year-old woman noted pain in the left foot after a shopping trip in July, 1979. Radiographs shortly thereafter were unrevealing. Pain recurred intermittently, followed by swelling over the dorsolateral aspect of the foot. In January, 1980, radiographs showed a lytic lesion laterally in the left cuneiform bone. Physical examination revealed only tender swelling dorsolaterally on the left foot. CBC and SMA-12 were normal. Five hours after the intravenous injection of 20 mCi of Tc-MDP, a drill bit was placed at the site of maximum count rate determined by intraoperative probing. The curretage specimen was interpreted as enchondroma.

Case No. 2. A 62-year-old man developed a wound infection after an elective insertion of a right iliac artery prosthesis. During a subsequent febrile course, gallium-67 imaging showed positivity in the right inguinal and femoral regions, and suppurating nodes were excised. The patient developed pain and exquisite tenderness in the region of the right superior iliac crest. Gallium-67 scan was positive in this area and was felt to represent an osteomyelitis. The patient was taken to surgery for a biopsy and culture from the iliac crest. However, intraoperative probing 8 days after the injection of 5 mCi of Ga-67 citrate revealed the maximum count rate to emanate from the soft tissue just superior and medial to the iliac crest. Guided by the probe, a soft-tissue abscess in the right iliac fossa was drained. All cultures were sterile.

TABLE 1. THE FULL WIDTH HALF MAXIMUM* OF THE LINE SPREAD FUNCTION FOR THE BIOPSY PROBE

Distance (cm)	FWHM (cm)
0	1
1	2
2	3
3	3.8
4	4.7

* The FWHM was measured in air with an extended source of Tc-99m.

Case No. 3. A 69-year-old woman developed insidious and progressive right knee pain 6 wk before admission. Radiographs and aspiration of the knee were both uninformative. Tomography was not performed. With the exception of proximal intraphalangeal (PIP) joint swelling of both hands, physical examination revealed only a tender effusion from the left knee with mild restriction of extension. The Tc-MDP bone survey showed striking positivity in both femoral condyles, with apparent joint involvement. Twenty-one hours after the intravenous injection of 20 mCi of Tc-MDP, a biopsy was taken at the most active site as determined by the intraoperative probe. The resulting presumptive diagnosis was acute transient osteoporosis.

Case No. 4. A 70-year-old man was found to have moderately differentiated adenocarcinoma upon transurethral prostatic resection in 1976. A technetium bone survey in 1978 was normal, but a follow-up survey in 1979 showed a single, focal lesion posteriorly in the left tenth rib. In February, 1980, this area showed fusiform enlargement. The patient remained asymptomatic. Complete blood count, SMA-12 chemistries, acid phosphatase, and chest radiographs were unrevealing. Detailed rib films were not made. Six hours after the intravenous injection of 2 mCi of Tc-MDP, a 5-cm portion of the tenth rib surrounding the area of maximum positivity was resected. Microscopy showed metastatic adenocarcinoma, with a cell pattern similar to that of the original prostatic primary. Six days later, a bone scan failed to reveal abnormal activity in this area (Fig. 2), thus suggesting total excision of the lesion identified preoperatively. (Interestingly, the ends of the resected rib were scintigraphically normal.)

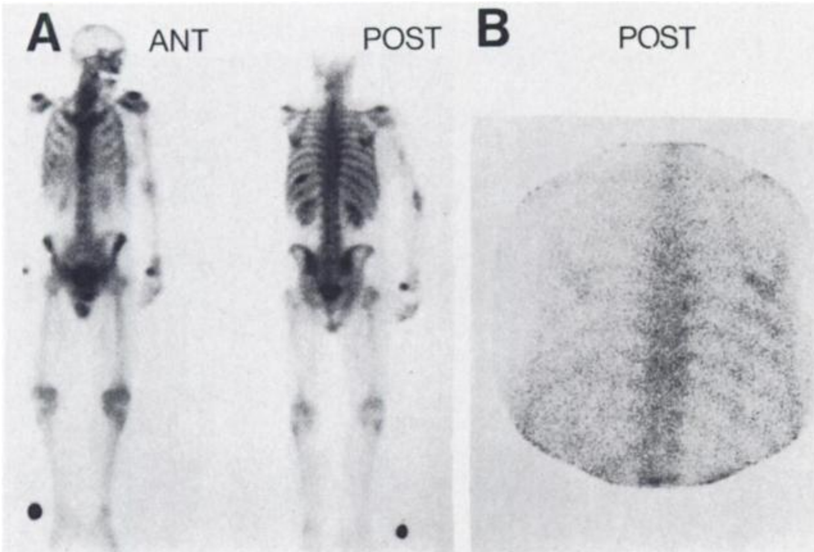

FIG. 2. Case No. 4, showing whole-body bone image with left posterior rib lesion before (A) and after (B) biopsy and excision.

DISCUSSION

The biopsy probe described here satisfies the desired requirements. The use of the small, flexible, fiberoptic cable as a light guide provides distinct advantages:

1. Since the diameter of the NaI(Tl) crystal is not limited by the size of the attached PMT, as in most current devices, the probe itself can be miniaturized.
2. The PMT is several feet from the probe head; therefore, high voltage is never near the patient during biopsy probing.
3. The 122-cm fiberoptic cable facilitates movement within a sterile field, as well as connection to the high-voltage supply and electronic unit outside the sterile field.

A disadvantage of the fiberoptic cable is the light losses inherent in such a system. Some major causes of optical energy loss are as follows: (a) reflection losses because of the added interfaces and the index of refraction (1.62) of the fiber bundle core; (b) packing losses due to the spaces between fibers; (c) spectral transmission losses within the glass-fiber cores, losing 80% at 380 mm, 40% at 410 mm, and 25% at 440 mm for the 122-cm cable; and (d) linear attenuation because of the length of the fiber bundle.

Light losses cause the probe system to have poor energy resolution, but this resolution seems to be of minimal importance for biopsy probing.

The maximum count rates observed in the region of interest have varied considerably. A rough estimate of the expected operating range is 10 K − 100 K cpm for patients probed 6 hr after the intravenous injection of 5 mCi Tc-99m-labeled MDP.

The utility of the probe has been verified in a small number of patients. Its primary use appears to be for lesions that are undetectable by radiography or are difficult to localize accurately by external techniques because of skin mobility, subcutaneous tissue, and intraoperative positioning and manipulation. Conceivably it may also have a role in pinpointing the most metabolically active portions of larger or more readily apparent lesions. While the instrument was designed primarily for use with technetium-99m, it appears to function well with the lowest energy peak of gallium-67 (Case No. 2). The fiberoptic probe is inexpensive and can easily be wedded to numerous scalers and rate meters already in the field.

Hand-held scintillation probes with a short, rigid, light pipe have been developed for thyroid surgery (*1,2*), but these are not practical for general use in biopsy and are not commercially available. In addition, miniature gamma detectors of gas-filled or solid state designs are available. Gas-filled detectors require a high voltage and offer lower sensitivity. Solid state detectors, such as cadmium telluride, require some voltage, and the detector as well as the associated electronics are expensive. We are not aware that a similar device meeting the criteria described above is currently available.

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