Determining the Cause of NaI Crystal Breakage

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By examining the fracture pattern in a damaged NaI crystal, it is possible to derive, a posteri, information concerning the cause of damage. One may, for example, distinguish mechanical shock from thermal shock. Aside from being of scientific interest, such information can help to identify the party responsible for breakage—be it manufacturer, shipper, user, or a hospital's heating maintenance department.

Nearly every nuclear medicine department has at one time or another had one of the sodium iodide crystals used in gamma cameras, probes, and well counters broken. Any cracks in these crystals will distort light transmission from the scintillation process and degrade the performance of the instrument, so that the crystal must be replaced. There may be doubts as to exactly how, when, and by whom the crystal was damaged. This can lead to questions of who should pay for a replacement and how a reoccurrence can be prevented. Ways to determine the nature of the cause by examining and characterizing breakage patterns are suggested.

Method and Discussion

Sodium iodide has a face-centered cubic crystal structure (*1*) and different mechanical properties in different directions. Within such a crystal there are planes of low cohesion that are especially susceptible to stress and it is along the "cleavage" planes that cracks are prone to occur if the crystal suffers a shock.

The first evidence of crystal damage in a gamma camera is usually the appearance of a bad flood picture during routine quality control checks. In many cases the presence of crystal damage is immediately obvious (Fig. 1). But sometimes (Fig. 2) it is not so obvious.

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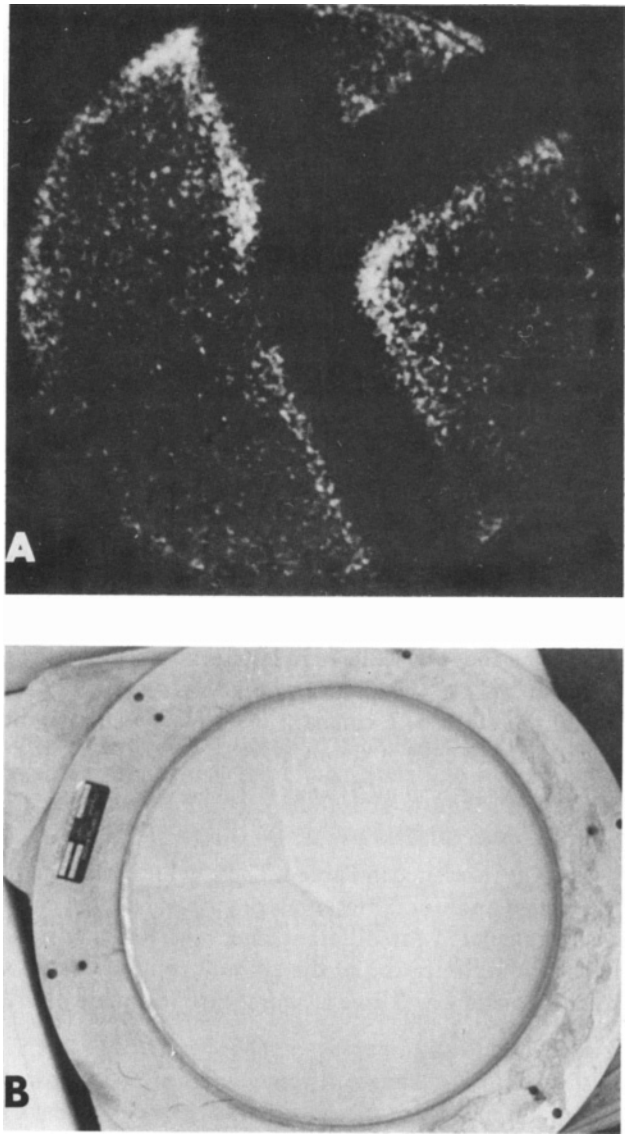

FIG. 1. (A) Flood shows obvious crystal damage; (B) actual crystal shown in 1A.

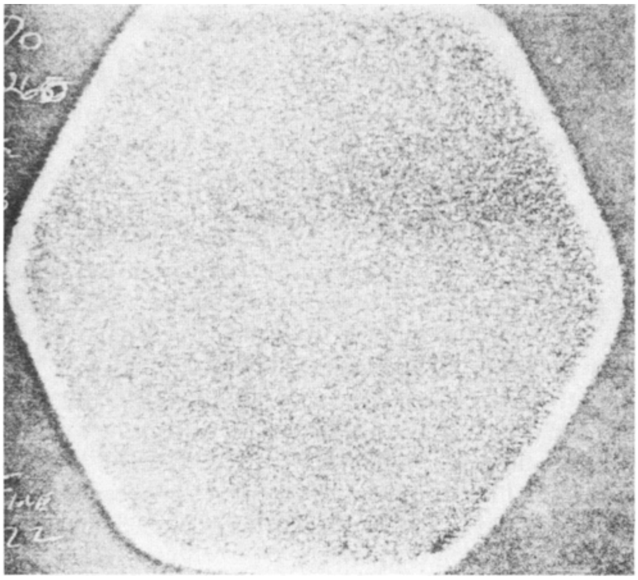

FIG. 2. Flood shows no sign of crystal damage. Crystal contained a small localized star-shaped crack in upper right edge and was replaced before damage progressed.

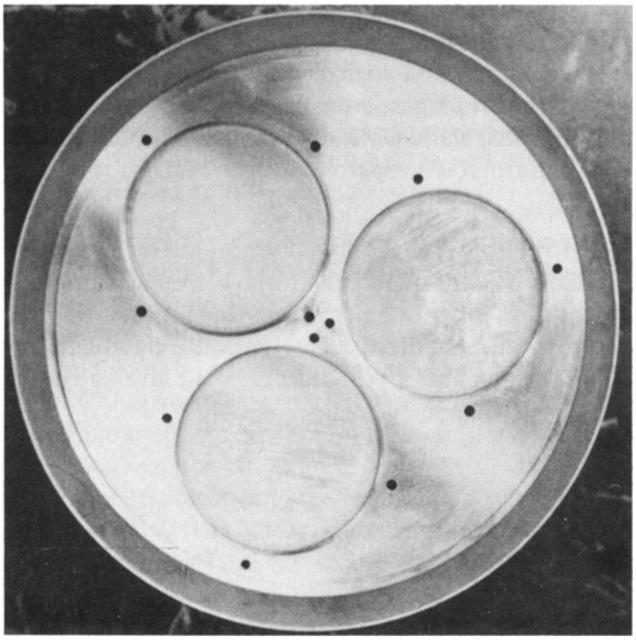

FIG. 3. Probe crystal probably damaged by overtightening P-M tube mounting bolts or during removal of same. Third P-M tube was properly handled and resulted in no damage. Local intense cracking associated with other two tubes is typical of mechanical damage.

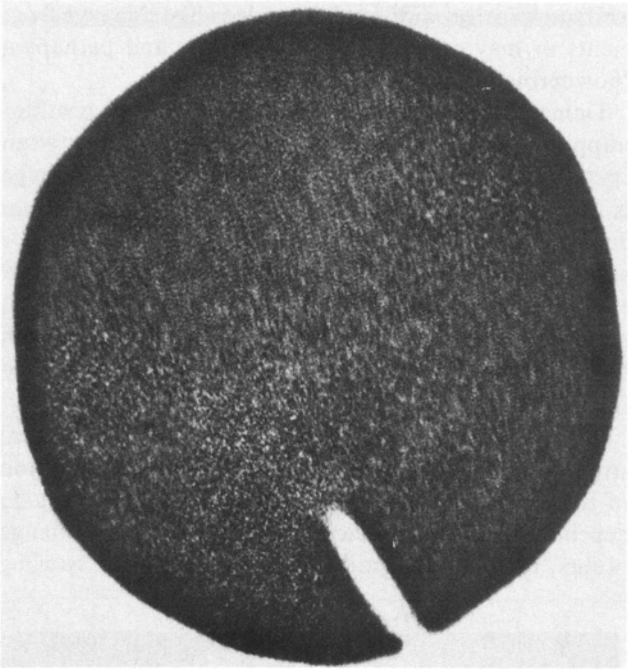

FIG. 4. Flood shows local damage caused by trapping a screw during collimator change.

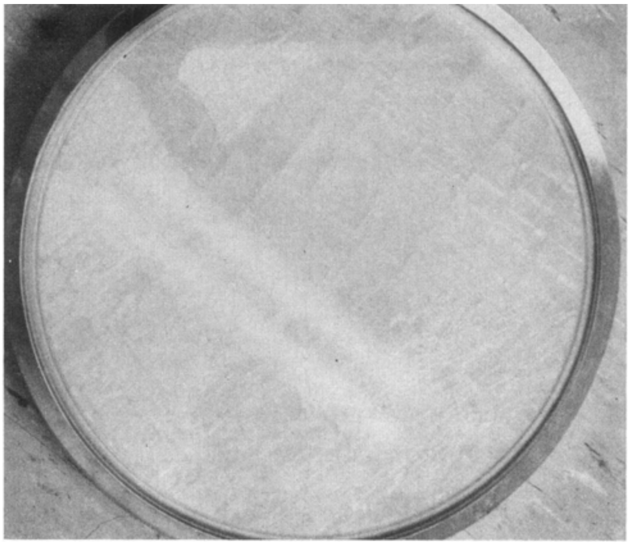

FIG. 5. Crystal originally damaged by thermal shock results in pattern of regular wide-spaced cracks shown in upper half. Subsequent careless handling produced more intense mechanical damage pattern in lower half.

Damage to crystals in scanner heads can be more difficult to spot and may only be revealed as increases in full-width-half-maximum (FWHM) energy resolution, which is not normally checked on a routine basis. Consequently the clinical picture quality degrades.

Damage to NaI crystals occurs either mechanically or thermally.

Mechanical damage: There are two subgroups of mechanical damage, a sharp blow or fall; and a steadily increasing pressure. Both groups, however, have one thing in common that helps distinguish mechanical damage from thermal damage: mechanical shock usually results in a localized area of higher crack density. The region of the crystal that actually receives the blow will be subjected to a higher intensity shock than the rest of the crystal. In this region the shock intensity will be sufficient to cleave some of the stronger crystal planes as well as the weaker ones. Indeed, if the blow is strong enough, the immediate location will break into plate-like cleavage fragments or may exhibit irregular fracture and perhaps a "powdering" effect.

Damage in the latter subgroup is usually the result of trapping a foreign object, such as a screw or bolt, between crystal and collimator. In this case localization of damage is usually quite marked and accompanied by an exterior dent in the aluminum canning of the crystal. It should be noted that a small localized defect may not be immediately evident from a flood study, but over a period of time it may develop into more extensive and apparent damage. In such cases it is sometimes difficult to link initial cause to final result.

Thermal damage: Thermal stress is indirect mechanical stress induced by differential expansion or contraction of the crystal. Rate of heat conduction is directionally dependent and if a sufficiently rapid temperature change occurs, temperature gradients will be built up, causing differential expansion and cleaving along weaker planes. It is fair to assume that any crystal subjected to extensive stress will yield at its weakest points. It is also possible that these loosely bound plane surfaces are thermal barriers; therefore, they are the very places one might expect the largest temperature gradients and hence the largest stresses to occur.

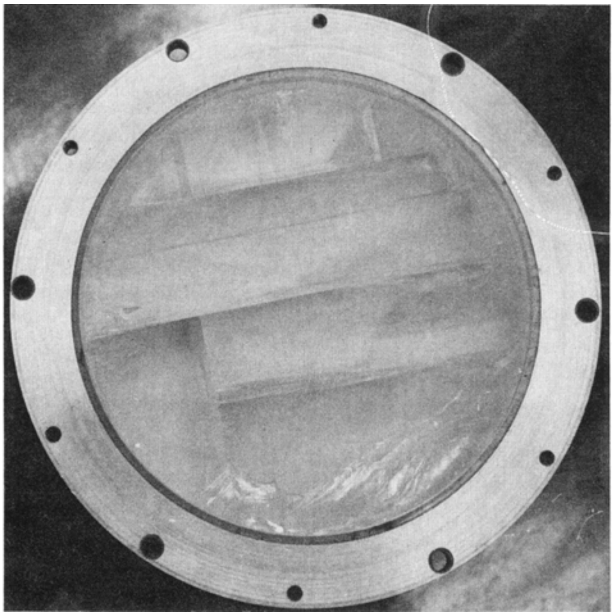

FIG. 6. Crystal damaged by thermal shock.

As with mechanical stress, the number of cracks or crack density will depend on the severity of the stress. Thermal damage, however, is characterized by a more extensive, uniform pattern of damage with no particular focal point or irregular breakage on it.

Thermal stress may also be caused by the differential expansion of crystal housing materials, such as the window to which the crystal is epoxied.

Figures 1 to 6 illustrate crystals that have been broken in various ways; they are from a survey carried out in the Eastern Great Lakes area.

Conclusion

There are three main causes for damage to NaI crystals resulting in different characteristic fracture patterns:

- A sharp blow or fall causing a region of localized intense damage as well as more wide-spread damage;
- Pressure from a small object causing imprint damage to the canning material as well as the crystal; and
- Thermal damage leading to a wide-spread, fairly uniform fracture pattern with no evident focal point.

Acknowledgment

I thank Ms. Martha Bennett who helped with preparation of this report and all the departments that provided information about the incidents. I am also grateful to Drs. D.H.I. Feiglin and E.W. Spiers for their invaluable suggestions and encouragement.

Reference

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