# TECHNIQUES OF MEASUREMENT OF IMPACT RESPONSE OF THE THORAX IN BIOMECHANICAL EXPERIMENTS—PART I: INSTRUMENTATION

by G.S. Nusholtz

## METHODOLOGY

Blunt non-penetrating thoracic impacts to human surrogates have been studied at the University of Michigan Transportation Research Institute (UMTRI) for several years.[1,2] These experiments are re-creations of impact environments which might have occurred as a result of a sports accident, an industrial/military accident, or an automotive crash. Most of the experimental work has utilized the repressurized human cadaver as the impact-test subject, although infrequent comparative analyses have utilized animals. The test subject is surgically instrumented prior to testing with mounting platforms for the accelerometers, pressure transducers, or other recording devices. Later, a detailed autopsy or necropsy is performed to record the damages resulting from the impact testing.

The testing equipment usually includes: (1) an impact device to deliver a calibrated amount of energy to the thorax, (2) a timing-control unit to synchronize the electronic equipment associated with a 10-100 ms impact time frame, (3) a high-speed X-ray cineradiograph or cameras and lights to photographically record gross motion of the test subject, (4) electromechanical accelerometers, pressure transducers, strain gages, and associated amplifiers used to measure the kinematic response (output) for a given impact condition, (5) test-subject repressurization equipment, and (6) FM data tape recorders to obtain electromechanical transducer time histories. Supporting systems are sometimes required to pre-position the test subject in a precise postural configuration prior to impact.

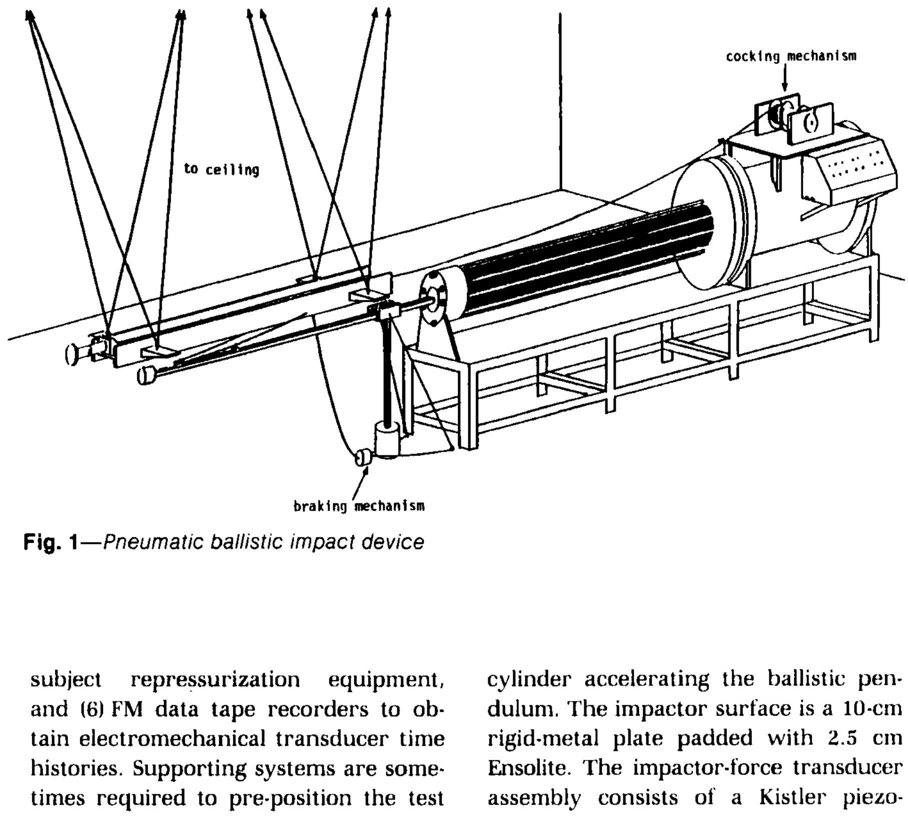


**Fig. 1**—*Pneumatic ballistic impact device*

**Pneumatic Impacting Device**—The UMTRI pneumatic ballistic impact device (Fig. 1) consists of an air reservoir, a ground and honed cylinder, and a carefully fitted piston mechanically coupled to a ballistic pendulum. Compressed air from the building's air compression system is introduced into the reservoir. The driver piston is secured at the reservoir end of the cylinder by an electronically controlled locking mechanism. When the air reservoir is pressurized and the locking mechanism released, the driver piston is propelled by the compressed air through the cylinder accelerating the ballistic pendulum. The impactor surface is a 10-cm rigid-metal plate padded with 2.5 cm Ensolite. The impactor-force transducer assembly consists of a Kistler piezoelectric load washer with a Kistler piezoelectric accelerometer mounted internally for inertial compensation.

To document the kinematic response of the subjects, arrays of accelerometers were affixed to the thorax of each subject. The thorax was instrumented with 18 accelerometers; triaxial accelerometer clusters were rigidly attached to the right and left fourth ribs, upper sternum, and T1 and T12 thoracic vertebrae. Single accelerometers were affixed to the right and left eighth ribs and lower sternum. Surgical instrumentation involved rigidly affixing accelerometer mounting seat forms to the skeletal thorax.

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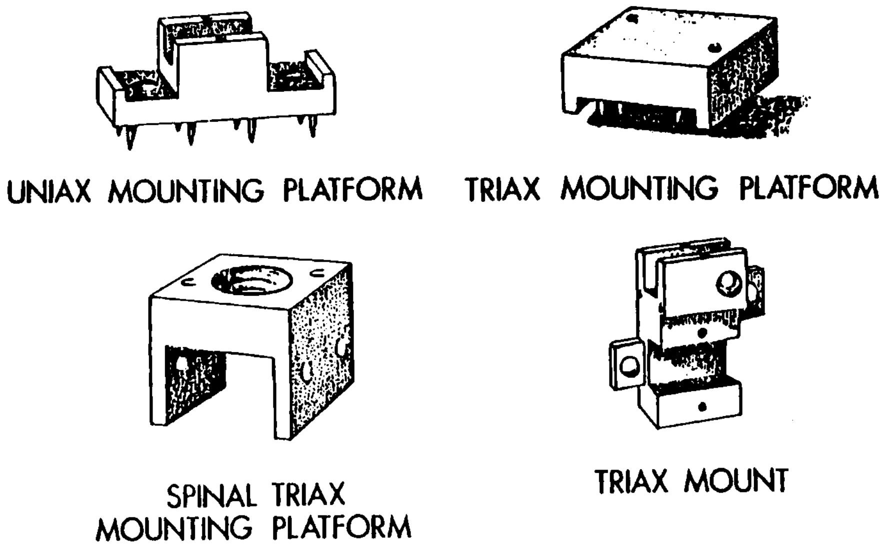
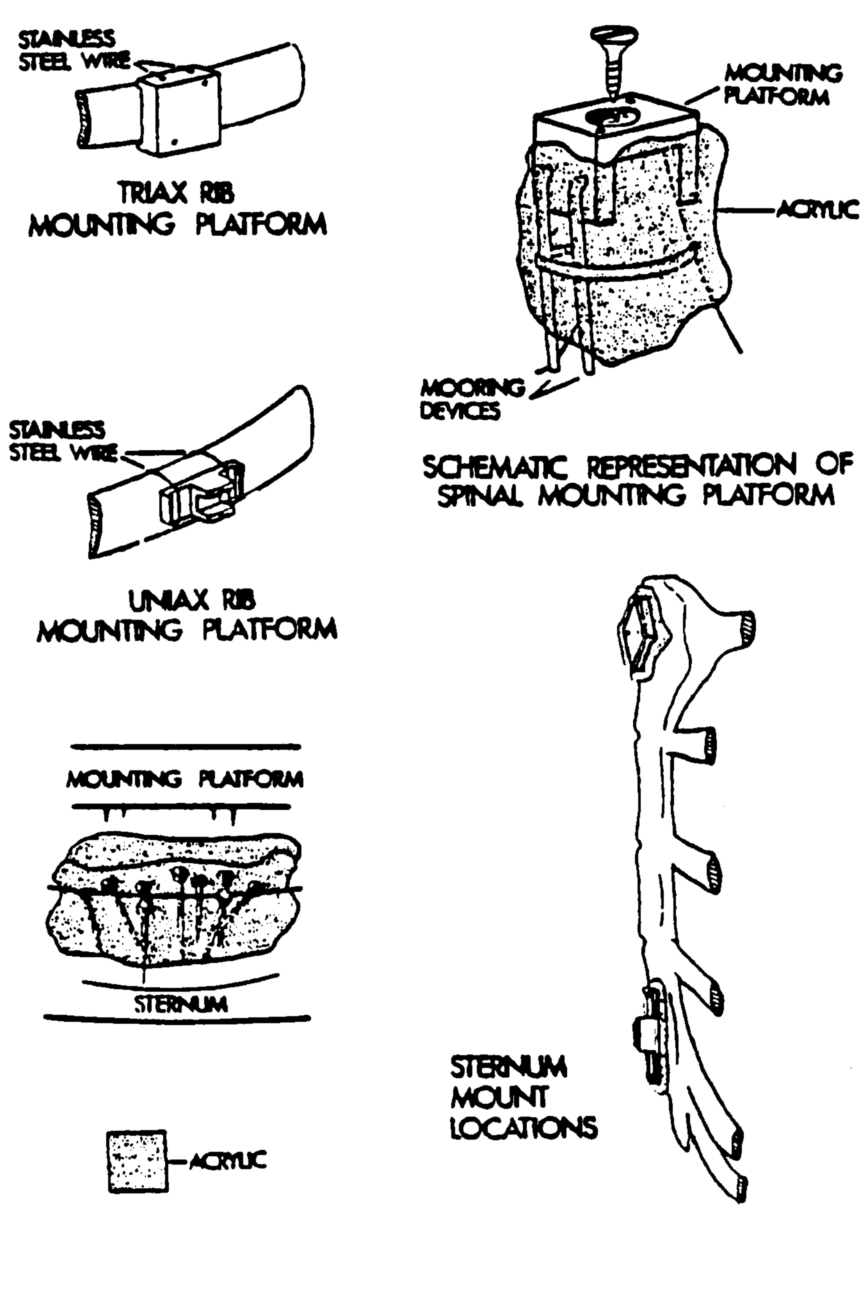



**Fig. 2**—*Mounting platforms and triax mount*




**Sternum**—Incisions were made at the attachment points on the sternum for the mounts. Small braided nails were tapped into the sternum, encased in acrylic, and the accelerometer mounting platform was embedded into the acrylic (Figs. 2, 3).

**Ribs**—Incisions were made over the fourth and eighth ribs on each side, so that the flat part of the exposed rib was normal to the lateral (anatomical) direction. To ensure rigidity, the mounts were fitted with pins and tied with wire to the flat surface of each exposed rib (Figs. 2, 3).

**Fig. 3**—*Location of mounting platforms*

**Spine**—Incisions were made over the vertebrae. Lateral supports for the accelerometer mounts were anchored on the lamina bilaterally, so that they would flank the spinous process. The accelerometer mount itself was fitted over these supports and screwed directly into the spinous process. Acrylic was applied under and around the mounts to ensure rigidity (Figs. 2, 3).

**Photokinemetrics**—High-speed photographic coverage of the test consisted of two lateral views. A Hycam camera operating at 3000 frames per second provided a close-up view of the thorax, while a Photosonics 1B camera operating at 1000 frames per second recorded an overall view of the test subject during the impact. The motion of the subject was determined from the film by following the motion of five-point phototargets on the acromion and sternum, as well as "single-point" phototargets on the head and impactor piston.

**Application**—Analysis of the photogrammetric data and electromechanical signals provides a framework in which parameters such as forces, velocities, accelerations, and rotations can be used to describe kinematic motion and mechanisms of injury. This information then can be used for designing protective devices as well as for more advanced modelling of the observed biomechanical system. In these thoracic studies, the final goal was to understand biological material (e.g., the thorax), consisting of both hard and soft tissues, in terms of both the time and frequency domains.

## ACKNOWLEDGMENTS

This work was conducted under the sponsorship of the National Highway Traffic Safety Administration, Contract Nos. DTNH22-83-C-17019 and DTNH22-83-C-07095. The author gratefully acknowledges the contributions of Robert Bennett, Richard Lehman, Valerie Karime, Bryan Suggitt, and Patricia Kaiker.

The protocol for the use of cadavers in these experiments was approved by the University of Michigan Medical Center and followed guidelines by the U.S. Public Health Service and those recommended by the National Academy of Sciences, National Research Council. Animals were handled according to the American Association for the Accreditation of Laboratory Animal Care and National Institutes of Health guidelines.

## REFERENCES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*Editor's Note: Part II of this article will appear in the December 1986 issue of E/T.*