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INSUFFICIENCY OF THE HEAD INJURY CRITERION AS A MEASURE OF IMPACT SEVERITY

T. B. Khalil and D. C. Viano
Biomedical Science Department
General Motors Research Laboratories
Warren, Michigan 48090

Abstract

The Head Injury Criterion (HIC) assesses the potential for brain injury on the basis of translational acceleration of the head center of gravity (CG). The genesis of HIC can be traced to Wayne State University's cerebral concussion curve which relates the onset of cerebral concussion to anteroposterior acceleration at the occipital region of the head. However, there is mounting experimental evidence that brain injury is related to both translational and rotational acceleration of the head. Since impact typically produces translation and rotation about the head CG, the CG HIC is not an accurate measure of the impact severity at all locations in the brain, especially at the brain-skull interface.

Rigid body motion can be uniquely described by translation of the CG and rotation about orthogonal axes at the CG. Assuming the head is a rigid body, the acceleration at any point in the head is: $\ddot{\underline{x}}(t) + \ddot{\underline{\theta}}(t) \times \underline{r} + \dot{\underline{\theta}}(t) \times [\dot{\underline{\theta}}(t) \times \underline{r}]$. Here, $\ddot{\underline{x}}(t)$ is translational acceleration of the CG, $\dot{\underline{\theta}}(t)$ and $\ddot{\underline{\theta}}(t)$ are rotational velocity and acceleration about the CG, and $\underline{r}$ is the distance from the CG.

The effect of $\ddot{\theta}(t)$ and $\ddot{x}(t)$ on the value of HIC at point P — the brain-skull interface — is additive and was analyzed using half-sine, triangular and square pulses with durations from 5 to 50 ms. If the centripetal acceleration is disregarded, linear relationships exist between $\ddot{x}$ and $\ddot{\theta}$, for a constant HIC at P (Figure 1); whereas, the value of CG HIC is constant for a given level of $\ddot{x}$ and T, regardless of the level of $\ddot{\theta}$. The magnitude of HIC at P (Figure 2) depends signficantly on the translational and rotational accelerations for a given pulse duration. Accordingly, the CG HIC may be very different from HIC at the site of potential injury.

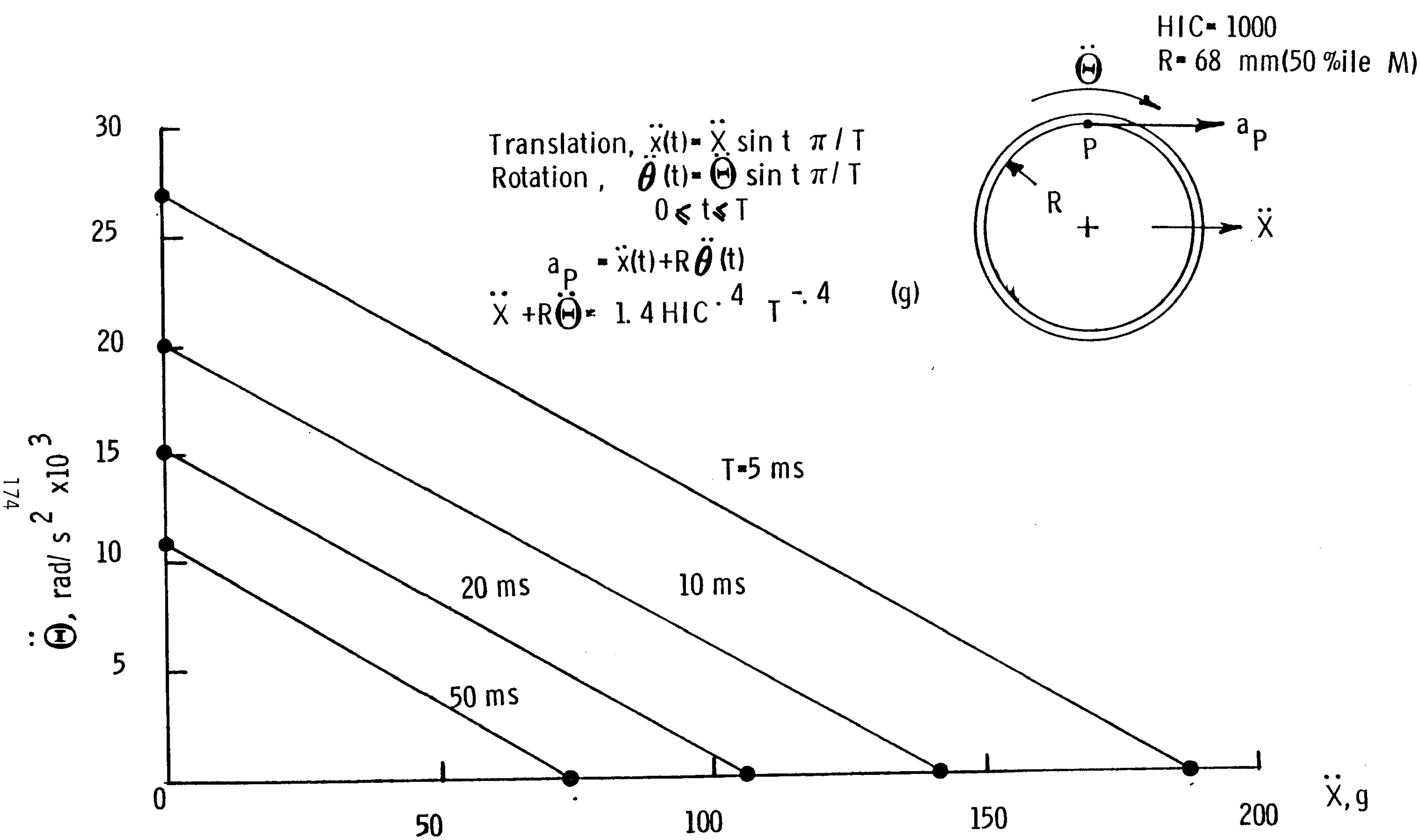

Figure 1 Relations between peak rotational ($\ddot{\Theta}$) and translational ($\ddot{X}$) accelerations at skull-brain interface for pulse durations from 5 to 50 ms at HIC=1000.

Different relationships exist at other points in the head

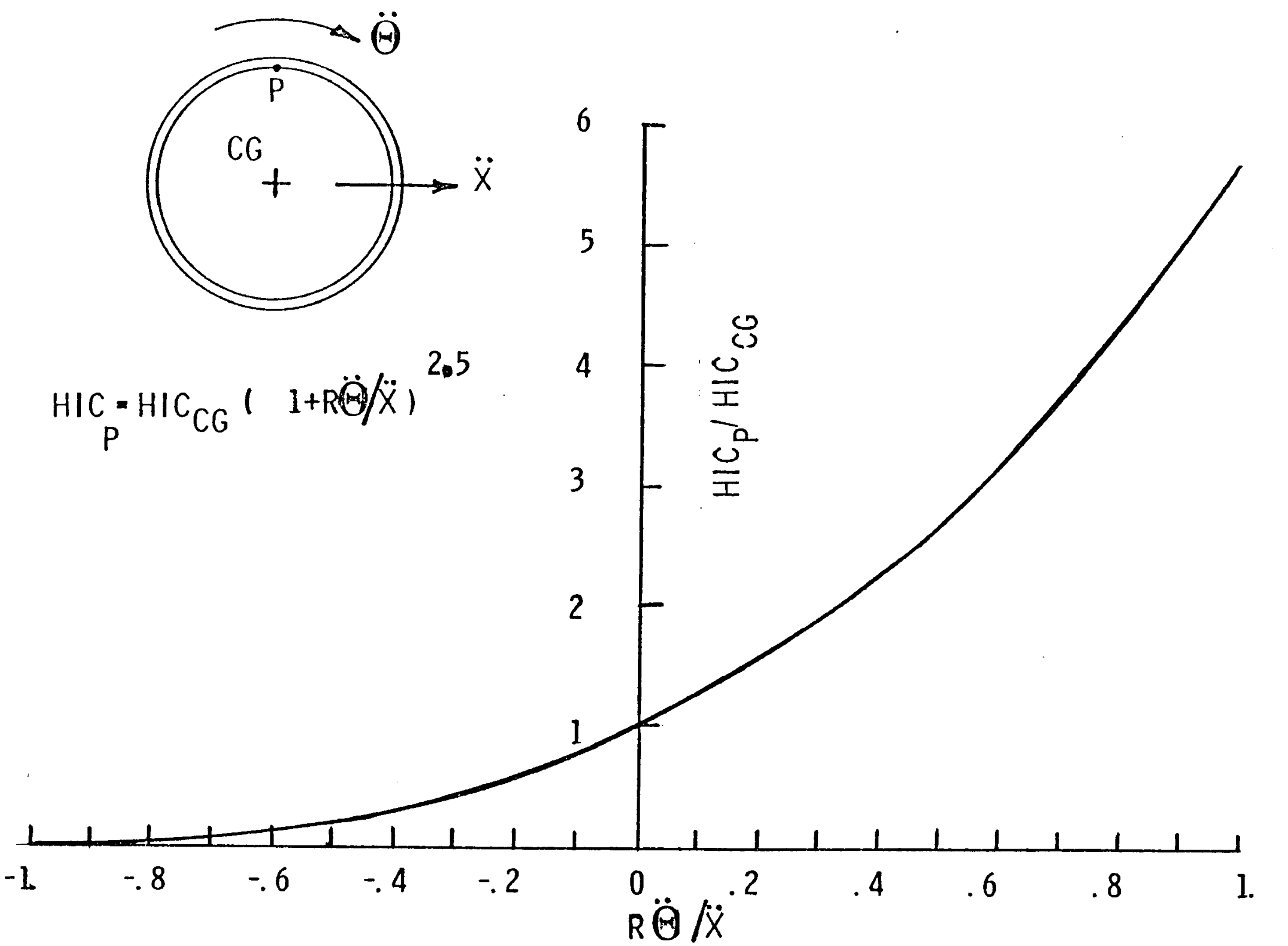

Figure 2 The rotational acceleration $\ddot{\theta}$ has a nonlinear effect on the magnitude of HIC at skull-brain interface, point P. $HIC_P = HIC_{CG}$ only in pure translation, otherwise HIC_P may be smaller or larger than HIC_{CG}.