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RISK AND LOSS ASSOCIATED WITH GEOLOGICAL, SOCIETAL, AND STRUCTURAL HAZARDS RELATED TO EARTHQUAKES IN URBAN LOS ANGELES COUNTY

Maya Mahue-Giangreco, M.S.
Epidemiologist, Injury and Violence Prevention Program
Los Angeles County Department of Health Services
7260 W. 80th Street
Los Angeles, CA 90045
Ph: (310) 410-0483
Fax: (310) 410-0433
Email: mahue@hsc.usc.edu

TECHNICAL ABSTRACT

This study is a follow-up to a preliminary descriptive epidemiologic study describing the characteristics of patients that were treated for injuries at a sample of emergency departments in Los Angeles County after the 1994 Northridge Earthquake. The specific problem that is addressed in this study involves improving methodology regarding estimation of injuries and death due to earthquakes by employing epidemiologic investigational techniques to obtain geographic locations of patients who sought care at a sample of emergency departments for injuries resulting from the 1994 Northridge earthquake. Estimates of casualties associated with earthquakes do not typically employ real data, but depend heavily on simulated data. Conclusions based on simulated data may be misleading. This methodology can be improved by comparing estimates obtained from simulations to those obtained using real data, as in this study.

Data were reviewed from four hospitals in heavily-impacted areas of Los Angeles County that were functional during the Northridge earthquake and had catchment areas spanning the Santa Clarita Valley, San Fernando Valley, West Los Angeles, Santa Monica, South-Bay and South-Central Los Angeles. In order to estimate changes in normal emergency department activity, baseline data was obtained for a two-week period prior to the earthquake. In order to obtain mechanism of injury and circumstances including the address of the injury scene, medical record review was necessary. Patient demographics (age, gender, ethnicity), as well as injury details (body location of injury, mechanism of injury) and hospital visit details (disposition from the facility, length of time spent in the emergency department, mode of arrival) were abstracted when available for 4,190 records.

Cases of earthquake-related injuries were clearly defined as such in the medical record or were identified as having been injured at the time of the earthquake (about 4:30 a.m. January 17, 1994). Assumptions regarding earthquake-related injuries were based on statistically significant increases in frequency of visits to the emergency department during the week after the earthquake compared to the rest of the month of January, 1994,

controlling for day of the week and facility. Earthquake-related injuries were scored with the standard Injury Severity Score (ISS). Data were then merged with Los Angeles County Assessor's tax roles by address. Information obtained from tax roles included (when available) square footage of the building and unit, structure use, year of construction, and type of construction. Data were also merged with Los Angeles City Building and Safety Inspection reports reflecting damage tagging placards for structures that had been inspected after the earthquake. Records that matched the Assessor's database were then merged by real estate parcel number to the California Governor's Office of Emergency Services (OES) Damage Database, developed by EQE, International in conjunction with OES. Information available in the damage database included estimates of Modified Mercalli Intensity (MMI), peak ground acceleration (PGA), and Evernden 2.5" Soil Code estimates. Proportion polytomous logistic regression and dichotomous logistic regression were performed to obtain estimates of risk associated with all available variables in relation to a 3-level ordinal outcome variable of injury severity (based on the ISS). Hierarchical models were compared using likelihood ratio tests in order to establish optimal yet parsimonious representations of relationships.

A total of 641 injuries had sufficient information for injury severity scoring. Overall, 69% of these records were matched to the Assessor's database. Descriptive statistics showed that more females were treated for earthquake-related injuries than males, and more people aged 30-40 were treated compared to any other 10-year age group. Caucasians were treated more than any other ethnic group. More injuries were caused by striking mechanisms (being struck by or hit by an object) than any other mechanism. The body location most often impacted by the injury was the lower extremity. Nearly all of the structures associated with injury scenes were wood-framed residences. Other engineering and geologic characteristics were more equally distributed. Only 100 residences reflected damage inspection reports.

The most consistent significant finding was regarding mechanism of injury. Falls were associated with more severe injury throughout the modeling process, even after adjusting for age, ethnicity, gender, body location of injury, structure use, year of construction, MMI, PGA, and soil code. Additionally, people over aged 60 were at increased risk for more severe injury after controlling for ethnicity, gender, body location of injury, mechanism of injury, structure use, year of construction, MMI, PGA, and soil code. Structural damage, as reflected in city building inspection reports, was not associated with more severe injury. Buildings built prior to 1976 were associated with increased risk for more severe injury after controlling for age, ethnicity, gender and structure use. Confounding bias due to patient demographics was detected between year of construction and injury severity. Those patients injured in multi-family housing relative to single or duplex housing were at an increased risk for more severe injury after adjusting for age, gender, ethnicity, body location of injury, mechanism of injury, MMI, PGA, and soil code. An interaction was inconsistently detected at various stages of modeling between year of construction and structure use. MMI and soil code were not associated with increased risk for more severe injury. The highest category of PGA (greater than 0.67 *g* in polytomous model, greater than 0.79 *g* in dichotomous model) was associated with increased risk for more severe injury after controlling for age, gender,

ethnicity, body location of injury, mechanism of injury, structure use, year of construction, MMI, and soil code. Confounding bias due to patient demographics was also detected between PGA and injury severity.

Agreement between estimates of injury rates based on observed injuries in selected census tracts and those estimated using EQE, International's Early Post-Earthquake Damage Assessment Tool (EPEDAT) software were within an acceptable 2 standard deviation range for EPEDAT-ATC injury rates. Agreement did not coincide as well with the EPEDAT-Whitman rates, which were much higher.

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Fax: (310) 410-0433
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NON-TECHNICAL ABSTRACT

This study is a follow-up to a preliminary descriptive epidemiologic study describing the characteristics of patients that were treated for injuries at a sample of emergency departments in Los Angeles County after the 1994 Northridge Earthquake. Real injury data has been obtained based on medical records, and has been matched to building characteristics and geologic details in order to estimate risk factors associated with moderate and severe injuries in an urban earthquake.

Data were reviewed from four hospitals in heavily-impacted areas of Los Angeles County that were functional during the Northridge earthquake and had catchment areas spanning the Santa Clarita Valley, San Fernando Valley, West Los Angeles, Santa Monica, South-Bay and South-Central Los Angeles. In order to estimate changes in normal emergency department activity, baseline data was obtained for a two-week period prior to the earthquake. In order to obtain mechanism of injury and circumstances including the address of the injury scene, medical record review was necessary. Patient demographics (age, gender, ethnicity), as well as injury details (body location of injury, mechanism of injury) and hospital visit details (disposition from the facility, length of time spent in the emergency department, mode of arrival) were abstracted when available for 4,190 records.

Cases of earthquake-related injuries were clearly defined as such in the medical record or were identified as having been injured at the time of the earthquake (about 4:30 a.m. January 17, 1994). Assumptions regarding earthquake-related injuries were based on statistically significant increases in visits to the emergency department during the week after the earthquake compared to the rest of the month of January, 1994. Earthquake-related injuries were scored with the standard Injury Severity Score (ISS). Data were then merged with Los Angeles County Assessor's tax roles. Information obtained from tax roles included (when available) square footage of the building and unit, structure use, year of construction, and type of construction. Data were also merged with Los Angeles City Building and Safety Inspection reports reflecting damage for structures

that had been inspected after the earthquake. Records that matched the Assessor's database were then merged to the California Governor's Office of Emergency Services (OES) Damage Database, developed by EQE, International in conjunction with OES. Information available in the damage database included estimates of Modified Mercalli Intensity (MMI), peak ground acceleration (PGA), and Evernden 2.5" Soil Code estimates. Estimates of risk associated with all available variables in relation to 3 levels of injury severity (minor, moderate, and severe) were obtained using standard statistical techniques.

A total of 641 injuries had sufficient information for injury severity scoring. Overall, 69% of these records were matched to the Assessor's database. Descriptive statistics showed that more females were treated for earthquake-related injuries than males, and more people aged 30-40 were treated compared to any other 10-year age group. Caucasians were treated more than any other ethnic group. More injuries were caused by striking mechanisms (being struck by or hit by an object) than any other mechanism. The body location most often impacted by the injury was the lower extremity. Nearly all of the structures associated with injury scenes were wood-framed residences. Other engineering and geologic characteristics were more equally distributed. Only 100 residences reflected damage inspection reports.

The most consistent significant finding was regarding mechanism of injury. Falls were associated with more severe injury throughout the modeling process, even after adjusting for age, ethnicity, gender, body location of injury, structure use, year of construction, MMI, PGA, and soil code. Additionally, people over aged 60 were at increased risk for more severe injury after controlling for ethnicity, gender, body location of injury, mechanism of injury, structure use, year of construction, MMI, PGA, and soil code. Structural damage, as reflected in city building inspection reports, was not associated with more severe injury. Buildings built prior to 1976 were associated with increased risk for more severe injury after controlling for age, ethnicity, gender and structure use. Those patients injured in multi-family housing relative to single or duplex housing were at an increased risk for more severe injury after adjusting for age, gender, ethnicity, body location of injury, mechanism of injury, MMI, PGA, and soil code. MMI and soil code were not associated with increased risk for more severe injury. The highest category of PGA was associated with increased risk for more severe injury after controlling for age, gender, ethnicity, body location of injury, mechanism of injury, structure use, year of construction, MMI, and soil code.