JASON MEGGS
May 10, 2008
PH 254: Proposal 2

PROSPECTIVE STUDY
TRANSIT NOISE AND HEART ATTACKS

1. Background

Noise is a major health problem around the world, particularly important in cities where heightened exposures to large populations are found. The European Commission has identified traffic noise as a primary public health problem and is mobilizing to address it[1,2]. Noise from traffic has been shown to impact sleep (Ising, 2004); cause increased heart attacks (acute myocardial infarction, or AMI), and ischemic heart disease (Babisch, 2008); and cause hypertension (Leon Bluhm, Berglind, Nordling, & Rosenlund, 2007). Noise creates stress, and "there is overwhelming evidence both for the deleterious effects of stress on the heart" (Dimsdale, 2008).

Heart disease is the leading cause of death in the United States, with the most common form being coronary heart disease, which leads to heart attack[3]. There were 451,236 deaths from coronary heart disease (heart attacks and angina) in the United States in 2004, 20% of overall mortality.[4] In the United States, in contrast to Europe, the EPA's Noise Control Division was terminated in the early 1980's by President Ronald Reagan (Broder, 1988), effectively freezing progress on this important public health issue, and resulting in an inability of transit service providers to use noise emission as a purchase criteria for transit vehicles when Federal funds are used (which is almost universally the case). As a result, transit vehicles are often louder than comparable vehicles.

Transit noise is thus particularly important because it operates around the clock, often in areas of highest population density. Night-time transit noise is of particular interest because it occurs during sleep, when populations are present and vulnerable, and when ambient noise is at its lowest, and thus may have the highest potential to cause harm.

2. The Conceptual Hypothesis

Transit noise increases the risk of heart attacks.

3. Identification of the study population

It is important to identify those who have high and low exposure to night-time transit noise, while ideally controlling for factors which may cause confounding. These two groups will

[1] http://ec.europa.eu/environment/noise/home.htm
[2] http://ec.europa.eu/commission_barroso/dimas/policies/noise/index_en.htm
[3] http://www.cdc.gov/heartdisease/
[4] http://www.americanheart.org/presenter.jhtml?identifier=4591

determine the cohort and reference populations (high and low exposure, respectively, but otherwise from similar environments, as would be preferred in an occupational study).

San Francisco offers a unique opportunity to study the effects of noise resulting from public transportation services. Numerous dense transit corridors[5] exist, along with numerous similar comparison corridors (without night-time transit noise). In particular, the Night Owl (all-night) service operates in only some transit corridors of the city, between 1 and 5 AM.[6] This arrangement provides the opportunity to conduct a natural experiment, observing the public health impacts of night-time transit noise.

Newly available data capabilities allow random selection of subjects and controls based on spatial criteria, to take advantage of place-based effects which are otherwise difficult to assess and correct for. Additionally information as to building age (which correlates well to internal noise levels) and newly developed noise contours (average ambient noise levels) can further inform the identification of comparable exposure and control groups. The effects of the Built Environment on health and other effects such as physical activity levels, SES, and air pollution exposures are increasingly studied, but still only partly understood.

However, it cannot be assumed that subjects are well selected simply on the basis of place. Detailed questionnaires and measured exposure assessments need to be completed. Moreover, buildings have remarkably different noise permeation characteristics, particularly depending on the degree to which windows are opened.

Kaiser Permanente (KP), a large HMO based in northern California, has many members in San Francisco and throughout the Bay Area. Cohort candidate populations can newly be generated using Geographic Information Science (GIS) mapping tools; members can then be randomly selected from within these areas with the help of spatial criteria, such as living on or near a certain street, or within a certain type of building. The cohort will thus include streets with night-time transit service, with controls on similar streets without night-time transit service.

Controls will be matched on age, and care should be taken that there is no imbalance as to gender and ethnicity (differing rates of heart attack are seen between races and genders[7]).

Those with outcomes should be screened for acute/special-case risk factors such as cocaine overdose and excluded on that basis (although perhaps noise drives some to drugs?).

If the cohort is to be large, finding enough subjects within San Francisco may become difficult. Fortunately, numerous urban areas around the Bay Area are included in the KP member-shed, have night-time transit, and moreover, may be more representative of U.S. cities as a whole and

[5] A “corridor” in the world of transportation planning refers to a route, but is not limited to any particular mode or structure; while a corridor may be as simple as a street, it may include bridges, tunnels, tracks and even helicopter routes on the same line. A corridor may include things, such as buildings, within a set distance (aka, buffer) around the corridor; for purposes of this study, those living on a corridor will be anyone deemed within exposure range.
[6] http://www.sfmta.com/cms/mmaps/official.htm
[7] age-adjusted prevalence of coronary heart disease for non-Hispanic whites is 9.4 percent for men and 6.0 percent for women; for non-Hispanic blacks, 7.1 percent for men and 7.8 percent for women; and for Mexican-Americans, 5.6 percent for men and 5.3 percent for women. http://www.americanheart.org/presenter.jhtml?identifier=4591

thus result in a range of environments. However, some of the benefits of San Francisco's unique and newly updated data may be lost. Because primary exposure data must be taken, this drawback may be minimized by selecting on true exposure metrics.

4. Statement of the operational hypothesis

Our hypothesis is that persons in homes with higher night-time transit noise will exhibit elevated incidence rate ratio (IRR) of heart attack as compared with similar members with lower night-time transit noise.

5. Assessment of exposure

Primary measurements, and validation of existing data, is the most reliable method of assessing exposure and the ability to do so is an essential benefit of choosing a *prospective cohort* study design. Direct measurement will capture unknown sources of noise, such as building noise, airplane frequency, snoring, construction, and neighbor noise, some of which, subjects may not even be aware of (as they are sleeping), and which may be difficult to quantify via subjective survey data, even if subjects were aware.

Measurements of exposure can be easily conducted by placing a noise meter overnight in the sleeping area. Digital recording allows a complete capture of the sound measured for identification purposes, along with computer-ready data describing the noise levels as measured throughout. A survey after each overnight measurement will assess whether the noise characteristics were abnormal in any way. Daytime measurements can also be taken; a stand-alone recording device might operate for an extended period, even a week. The cost per unit can be kept below $2,000 and the staff time to place and retrieve the units is minimized.

Assessment of sensitivity to noise, both through a hearing test and through survey questions as to perception, will also inform exposure assessment.

Survey questions will also need to assess time spent in various types of noisy environments including years at current residence, time period for sleeping, time spent at home, occupational noise, and information as to the noisiness of past occupations and residences. Years of residence are repeatedly indicated as highly determinative of effect in numerous noise studies.

<u>Existing knowledge and prediction of noise levels</u>

It is true that exposure to night-time transit noise can be predicted without the use of new measurements, based on available data and previously generated measurements. Given knowledge of the regular transit schedule, and the types of vehicles used, particularly with data regarding traffic volumes (particularly of trucks), one can estimate the ambient noise. Survey information will identify the location of the sleeping room with relation to the street, which has repeatedly been shown to modify risk for various outcomes. GIS datasets are available from the SF DPH indicating the age of the building, which is generally considered to be a good estimator for noise penetration into the sleeping area. Moreover, newly developed average noise contours for the entire city have just been released from SF DPH.

Transit types have differing noise emission characteristics (Staiano, 2001); a trolleybus, for example, averages 78 dBA, whereas a diesel bus may exceed 90 dBA, and hybrid diesels, newly in vogue, can be even louder; light rail is generally comparable with diesel or louder, and emits even greater vibration, which is similar to noise but cannot be as effectively protected against through building improvements. Transit corridors may use a mix of different technologies, which can change over time, however, trolleybuses and trains cannot be used at all without available infrastructure, so a clear higher-noise category exists wherever there is no trolleybus infrastructure, in the absence of quieter (e.g., hydrogen fuel cell and battery-electric) vehicles. SF DPH has generated data on San Francisco transit schedules.

6. Assessment of the health outcome

Cardiac arrest is a common occurrence with a fairly reliable diagnosis.

Criteria must be chosen for the determination of whether cardiac arrest has occurred, and these criteria should be checked against autopsy and other medical diagnosis records to maximize consistency of case identification.

7. The measure of effect

Incidence rate ratios (IRR) compared between exposure categories and the generalized population.

8. Adjustment of potential confounding

Survey data, medical records, and direct exposure measurements are necessary to assess sources of bias including confounding; smoking history and exposure and other risk factors for AMI.

The presence of indoor second hand smoke exacerbates the risk of heart attack (Dinno & Glantz, 2007), as does smoking in general, so smoking exposure must be adjusted for.

Potential confounders include the many environmental characteristics of a dense transit corridor which may also cause heart disease. By choosing controls on similar corridors, which differ primarily in night-time transit, many unidentified confounders may be equally distributed.

Exposure to traffic-related air pollution contributes to heart disease which leads to the occurrence of heart attack (Rosenlund, Picciotto, Forastiere, Stafoggia, & Perucci, 2008). This is also controlled by matching corridors with similar traffic-related pollution. The marginal addition of additional transit vehicle pollution is assumed to be insignificant, but worthy of further investigation, particularly when comparing electrified transit to diesel transit corridors.

The effect of window opening behavior is of concern; subjects may tend to close windows more if noise is a problem. This will lead to increased exposure to indoor air pollution, which contributes substantially to the burden of disease including heart attack. At the same time, it may reduce exposure to outdoor pollutants which cause heart attack. Inadequate epidemiology was identified as to this issue,although because night-time air is generally cleaner than daytime air, a safe assumption would be that open windows reduce exposure to pollutants which cause heart attack, while adding exposure to noise which may cause heart attack, so the bias would tend to cancel.

Lack of physical activity is said to double the risk of heart attack;[8] simply riding a bicycle for everyday errands can easily equate to 2,000 kCal/week, which is associated with a 20% reduction in heart attack[9] -- thus detailed information on exercise is important. Likewise, dietary habits are associated with heart attack risk.

Risk factors which medical records or an exam upon entry could inform include body-mass index (BMI), high blood pressure, diabetes, and any history of high cholesterol.[10] At the same time, blood pressure increases are associated with noise, so the history of blood pressure in relation to the history of noise exposure should be considered.

All of these potential confounders should be accounted for through carefully constructed survey questions, environmental measurements and data, and then adjusted for in analysis.

9. Study power

Given the high rate of heart attack in the population, it was thought that a prospective cohort of relatively small size would have adequate power. Age-adjusted prevalence for 2005 is shown in the below table (it is noted that death rates from chronic forms of Ischemic heart disease occured at almost twice the rate of heart attacks).

Table 10. Number of deaths from 113 selected causes by age: United States, 2005

Cause of death (Based on the *International Classification of Diseases, Tenth Revision*, 1992)	All ages	35-44 years	45-54 years	55-64 years	65-74 years	75-84 years	85 years and over
Ischemic heart diseases (I20-I25)	445,687	6,860	25,310	46,799	70,121	134,435	160,935
Acute myocardial infarction (I21-I22)	151,004	2,734	10,070	18,553	26,674	45,449	47,041
Other acute ischemic heart diseases (I24)	3,565	-	1	1	3	11	82
Other forms of chronic ischemic heart disease (I20,I25)	291,118	2	4	6	80	611	4,044

Table: Number of Deaths in the U.S., 2005, from various forms of heart disease (CDC).[11]

[8] http://www.oralchelation.com/heart/aha5.htm
[9] http://www.kenkifer.com/bikepages/health/pedal_h.htm
[10] http://www.cdc.gov/nccdphp/publications/factsheets/ChronicDisease/virginia.htm
[11] http://www.cdc.gov/nchs/data/nvsr/nvsr56/nvsr56_10.pdf

Thus there were 147,787 deaths from acute myocardial infarction in 2005; using U.S. Census population estimates for 2005,[12] the total population 45 years and over was 109,627,955. The rate per 100,000 was therefore 134.8. Oddly enough, this data and simply finding the age-adjusted mortality rate was difficult and took some searching; morbidity data was even more difficult to come by, as the only source found was a CDC source which lumps coronary heart disease, angina, and heart attack together as "diseases."[13] Genentech states that "as many as 700,000 people in the U.S. will have a coronary attack" each year.[14] Some sources indicated that 2/3 of heart attack victims survive. For now if we assume that to be true, then total annual heart attacks for those over age 45 should be roughly 450,000 per year, or approximately 410 per 100,000, and 4.1 per 1,000. If we take the relative risk to be at least 1.5 for the high versus low noise category, then 6.2 per 1,000 will experience heart attack in the high-noise cohort. To get a study power of at least 80%, using the tools available at OpenEpi.com, for a one-year study, the total number of subjects would have to be on the order of 20,000 exposed and 20,000 unexposed (comparison/referent group):

Power for Cohort Studies	
Input Data	
Two-sided confidence interval (%)	95
Number of exposed	20000
Risk of disease among exposed (%)	0.6157189
Number of non-exposed	20000
Risk of disease among non-exposed (%)	0.4104792
Risk ratio detected	1.5
Power based on:	
Normal approximation	81.93%
Normal approximation with continuity correction	80.01%

Table: Calculation of cohort size, 1-year, IRR=1.5, power > 80% at OpenEpi.com. (Dean, 2008)

It is quite possible, that when adjusting for all these factors in a cohort of this size, that a much stronger effect will be found; previous research has been inadequate in that it only studied ambient noise, and ignored intermittent peaks. If the indications are followed, then a risk ratio of over 2 is easy to conceive of, particularly given the data provided in Babisch (2008).

If a dynamic cohort is maintained for ten years, with an IRR of 2, then a smaller cohort size of only 2,200 in each category is possible:

Input Data

[12] http://www.census.gov/popest/national/asrh/NC-EST2005-sa.html
[13] http://www.cdc.gov/nchs/data/series/sr_10/sr10_235.pdf
[14] http://www.gene.com/gene/products/education/vascular/hrtattack-factsheet.html

Two-sided confidence interval (%)	95
Number of exposed	2200
Risk of disease among exposed (%)	1.23
Number of non-exposed	2200
Risk of disease among non-exposed (%)	0.41
Risk ratio detected	3
Power based on:	
Normal approximation	85.47%
Normal approximation with continuity correction	81.18%

Table: Calculation of cohort size for ten-year, IRR=2, power > 80% at OpenEpi.com. (Dean, 2008)

10. The main sources of potential bias in this study

Recall bias is a concern when assessing past noise exposure. Fortunately, a prospective study affords the opportunity to take measurements and surveys regarding the present, which should minimize this bias as the cohort moves forward. Direction of bias depends on whether there is over or under-reporting of exposure; however, because over-reporting is likely to correspond to individual sensitivities, which are presumed more likely than not to relate to actual stress experienced, bias away from the null is assumed to correspond to a real effect (and finding whether there is an effect is the main goal).

Confounding bias is a concern, as discussed above.

Information bias is a concern because even in a single health care provider's cohort, there will be variation in methods and reporting. Diagnosis methods vary. However, AMI is a common and fairly well understood event. Matching doctors' diagnoses with standard criteria will help assure consistency of case identification. Failure to identify cases should occur equally throughout the cohort, so bias would be toward the null.

11. The two greatest weaknesses of the proposed study

The foremost weakness is the narrowness of the outcome, long with the size and expense of studying such a narrow outcome, and whether the results will be extensible to other intermittent noise conditions and to noise conditions generally.

The second greatest weakness is the uncertainty as to future transit use in an age of declining oil reserves, alternative vehicle experiments, and steadily increasing challenges to financing mass transit. Changes that might be seen include increased night-time transit; switches to quieter vehicles (e.g., electric or fuel cell vehicles, although their adoption likelihood is questionable); declining transit use as costs become prohibitive; increased noise from freeways as the price of fuel shifts people to transit, reducing congestion; and decreased noise from airports as fuel prices put the final nail in the coffin of an already subsidized industry. If a ten-year cohort study is required, who knows what changes might occur in the meantime.

12. The greatest strength of the proposed study

The study benefits from assessing a stark black-and-white contrast between those exposed to night-time transit and those who aren't, in areas that are otherwise quite similar. Some areas of San Francisco are very quiet but for night-time transit, adding to the importance of the study. High exposure contrast and is critical to reliable identification of effect.

Moreover, detailed exposure assessment is a rarity in the sparse literature, which normally measures ambient levels, not actual penentration of the building, let alone subjects' hearing ability paired with subjective survey data.

13. Ethical issues and benefits to participants

No change in behavior is required of subjects, merely information as to noise exposure and factors relating to risk of heart attack. The survey and any follow-ups will be a relatively minimal imposition and will not require biological samples. Any medical tests (hearing, blood pressure, etc.) are generally routine and in the patient's interest to do, anyway.

On the other hand, collecting noise data while one sleeps, particularly if secondary identification recordings are conducted, where conversations are recorded, may change behavior and raises obvious privacy issues. It is hoped that in the event of recording noise, that a scrambler could be identified which would make conversations unintelligible. Software is available which can potentially integrate with recording methods to do this. Otherwise, survey questions to identify any unusual noise would be a best practice.

14. A rough estimate of study cost

For surveys, medical exams, and noise readings of each of 4,400 subjects plus overhead, salaries and other expenses, followed over ten years, see Table 2. This is hopefully an over-estimate.

Year	1	2 through 10	11	TOTAL
Overhead	60000	540000	60000	660000
KP Fees	800000	1800000	120000	2720000
Statistician	20000	45000	50000	115000
Principal	80000	360000	80000	520000
Survey costs	1600000	3600000	0	5200000
Supplies	200,000	180000		380,000
Publication			5000	5000
Presentation			20000	20000
TOTAL	**2760000**	**6525000**	**335000**	**9620000**

Table 2. Study cost estimate on an eleven-year plan.

15. Why this study should (or should not) be done

Yes, but.

That the issue needs to be studied is clear; the effects of noise on heart disease have only just begun to be studied and understood. No studies were found which studied transit noise, nor even the effects of intermittent noise, on heart disease.

The health burden is significant: so many in the U.S. and around the world are at risk, and indications are there will be a significant finding. A finding here might be generalized to other forms of intermittent night-time traffic, such as truck or train noise, building noise, and more. The cost of a prospective cohort study of this magnitude and complexity, for measuring such a narrowly defined effect, suggests that the study should be more broadly conceived to account for all or many forms of noise, and perhaps for more disease outcomes. It would be good, if possible, to be able to expand the category of heart disease in order to anticipate more cases and thus reduce cohort size, at the very least.

Given the power of GIS and the available datasets, a preliminary study of disease in proximity to night-time transit noise could be undertaken, with exposures estimated by general measurements and general characteristics, and could include many more subjects for much less cost, in a fraction of the time. Such a study might then be used as justification for more detailed and more expensive studies as needed, and might help identify diseases related to noise which are not yet understood.

A retrospective cohort study, using KP's new resource of place-based member selection, could be done – even without conducting surveys – in a similar way as aforementioned, at considerable cost and time savings. If an outcome not resulting in mortality, or a validation/estimation sub-sample is used of those who are still alive, is used, then survey data would make this approach even stronger. Other or even multiple diseases might be studied concurrently.

Blood pressure, for instance, is known to increase with noise and is indicative of risk for other conditions; blood pressure measurements are frequently recorded in charts and so a retrospective cohort study might be particularly feasible for large numbers of subjects. Blood pressure effects are much more frequently seen than heart attacks, which may result in part from heightened blood pressure.

Above all, the importance of noise is such that to go to such lengths only to study it so narrowly in terms of night-time transit alone, seems to miss the mark. A better study design would look at all noise and multiple outcomes, particularly when detailed exposure assessment is being conducted. The public health implications of such a study would surely be staggering.

Policy implications

Because transit agencies are unable to specify noise criteria when procuring fleets, which are major public investments with long-term implications for public health, exposing the true impacts of noisy vehicles may allow better decisions to be made through mechanisms such as environmental review processes in general, and Health Impact Assessment in particular. Moreover, mounting evidence of the human health care costs and suffering attributable to preventable noise emissions may afford a new political opportunity to revisit the termination of the EPA's Noise Control Division, which would surely have major human health, social and economic benefits. Finally, the less noisy alternative to diesel buses, electrified trolley buses, have numerous other health benefits including nearly eliminated air pollution, reduced vibration, and greenhouse gas emissions, and cost less overall despite higher up-front costs. If health impacts are better known, then the cost hurdle is more likely to be overcome. An extensive trolley bus network could lead to replacement of other harmful vehicles such as diesel trucks; overhead catenaries amortize well with increased usage. Electrification of burning fossil fuel-based transportation has major implications for sustainability, not least of which is health.

Additionally, policies on protecting building occupants from noise might ensue from a finding of effect; controlling outdoor noise is only one part of the intervention picture. Shoring up buildings against noise is another important practice which can be mandated in building codes and more.

Some hesitancy in investigating the health impacts of public transportation surely exist, owing in part to the many barriers to implementation which transit already suffers, along with a concern that the reputation of public transportation not be harmed. However, such hesitancy may commit an overall disservice if public health is not adequately protected; a centralized system of transport provides the opportunity to utilize best practices and protect rather than harm its users, particularly important as so many are exposed. Moreover, the public is not always ignorant of environmental factors deleterious to health, and may avoid the use of or resist new forms of transit service if those problems are not addressed. Providing best possible transit options will only boost the public transportation cause in the long-term.

References

Babisch, W. (2008). Road traffic noise and cardiovascular risk. *Noise Health, 10*(38), 27-33.

Broder, I. E. (1988). A study of the birth and death of a regulatory agenda – the case of the EPA Noise Program. *Evaluation Review, 12*(3), 291-309.

Dean AG, Sullivan KM, Soe MM. OpenEpi: Open Source Epidemiologic Statistics for Public Health, Version 2.2.1. www.OpenEpi.com, updated 2008/04/05, accessed 2008/05/13.

Dimsdale, J. E. (2008). Psychological stress and cardiovascular disease. *Journal of the American College of Cardiology, 51*(13), 1237-46.

Dinno, A., & Glantz, S. (2007). Clean indoor air laws immediately reduce heart attacks. *Preventive Medicine, 45*(1), 9-11.

Ising, H. (2004). Stress effects of noise in a field experiment in comparison to reactions to short term noise exposure in the laboratory. *Noise Health, 6*(24), 1-7.

Leon Bluhm, G., Berglind, N., Nordling, E., & Rosenlund, M. (2007). Road traffic noise and hypertension. *Occupational and Environmental Medicine, 64*(2), 122-6.

Rosenlund, M., Picciotto, S., Forastiere, F., Stafoggia, M., & Perucci, C. A. (2008). Traffic-related air pollution in relation to incidence and prognosis of coronary heart disease. *Epidemiology, 19*(1), 121-8.

Staiano, M. A. (2001). Comparison of light rail and bus transit noise impact estimates per federal and industry criteria. *Transportation Research Record,* (1756), 45-56.