Title: Use of multiple data sources for surveillance of work-related amputations in Massachusetts, comparison with official estimates and implications for national surveillance

Running title: Multisource surveillance of work-related amputations

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Use of multiple data sources for surveillance of work-related amputations in Massachusetts, comparison with official estimates and implications for national surveillance

Abstract

Background: Accurate **s**urveillance of work-related injuries is needed at national and state levels. We used multiple sources for surveillance of work-related amputations, compared findings with Survey of Occupational Injuries and Illnesses (SOII) estimates, and assessed generalizability to national surveillance.

Methods: Three data sources were used to enumerate work-related amputations in Massachusetts, 2007-2008. SOII eligible amputations were compared with SOII estimates.

Results: 787 amputations were enumerated, 52% ascertained through hospital records only, exceeding the SOII estimate (n=210). The estimated SOII undercount was 48% (95% CI: 36-61%). Additional amputations were reported in SOII as other injuries, accounting for about half the undercount. Proportionately more SOII estimated than multisource cases were in manufacturing and fewer in smaller establishments.

Conclusion: Multisource surveillance enhanced our ability to document work-related amputations in Massachusetts. While not feasible to implement for work-related conditions nationwide, it is useful in states. Better understanding of potential biases in SOII is needed.

Key words: work-related amputations, injury surveillance, underreporting, undercounting

Introduction

Occupational injuries and illnesses are a significant public health problem in the United States, imposing substantial human and economic costs [Leigh, 2011; Biddle, 2009]. Timely, accurate measures of the extent, nature and causes of work-related injuries and illnesses are essential to allocate limited prevention resources effectively and monitor progress in meeting prevention goals at both national and state levels. National surveillance data are needed to inform national prevention priorities, yet, relying on national statistics can obscure safety and health concerns that may be specific to a state. State surveillance data are needed to inform state occupational injury and illness prevention priorities and can also be a powerful means of garnering the support of local stakeholders necessary to address identified safety and health problems [CSTE, 2001].

The Census of Fatal Occupational Injuries (CFOI), a comprehensive national-state system using multiple data sources for case ascertainment, has been in place since the early 1990s [BLS, 2013]. However, surveillance of nonfatal occupational injuries and illnesses in the United States remains fragmented with significant gaps [IOM and NRC, 2009]. Official national and state estimates of nonfatal injuries and illnesses are based on the Survey of Occupational Injuries and Illnesses (SOII), conducted annually by the U.S. Bureau of Labor Statistics (BLS) with state agency partners [BLS, 2104]. Data from logs of work-related injuries and illnesses required to be maintained by the Occupational Safety and Health Administration (OSHA) are collected from a sample of approximately 250,000 private industry and state and local government establishments nationwide. Recordable injuries and illnesses include those resulting in medical treatment beyond first aid, loss of consciousness, one or more days away from work, restricted work activity or job transfer or other specific conditions [Wiatrowski, 2014, in this issue]. SOII excludes approximately 14% of the workforce, including the self-employed, federal and household workers, workers on small farms, and, until 2008, state and municipal workers who make up an additional 12% of the workforce [Dye et al., 2011]. It is well recognized that SOII does not capture long latency occupational illnesses, and there is increasing evidence that injuries

are also underreported [Nestoriak and Pierce, 2009; Ruser, 2010; Lipscomb et al., 2013]. Estimates of underreporting range widely, from 20% - 70% [Conway and Svenson, 1998; Leigh et al., 2004; Rosenman et al., 2006; Boden and Ozonoff, 2008]. A number of factors may discourage reporting by either workers or employers [Lessin and McQuiston, 2013]. There is also concern about differential reporting depending on characteristics of the worker, the injury or the employer establishment, as well as by geographic region [Azaroff et al., 2002; Azaroff et al., 2004; Friedman and Forst, 2007; Mendeloff and Burns, 2013]. Alternative approaches to nonfatal occupational injury and illness surveillance need to be explored.

The present study, part of a three-state effort sponsored by BLS, was undertaken by the Massachusetts Department of Public Health (MDPH) to pilot use of multiple data sources for surveillance of work-related amputations in Massachusetts, compare multisource findings with state estimates from the SOII, and assess the generalizability of this approach to national surveillance. BLS chose amputations for this study as an example of a serious work-related health condition that should be relatively easy to recognize and attribute to work.

Methods

Surveillance case definition

A work-related amputation was defined as the loss of a protruding body part involving bone loss due to a traumatic incident with evidence of work-relatedness. Eligible body parts included all or part of the upper or lower limbs. If bone loss could not be determined in the available records, it was assumed and the case was considered to meet the surveillance case definition. This approach was consistent with the BLS protocol for assigning amputation codes according to the Occupational Injury and Illness Classification System (OIICS) in place during the study period [BLS, 2007].[1] Amputations can occur immediately during an incident or be delayed days or

[1] According to OIICS coding protocols in place during 2007-08, an injury reported as an amputation involving a limb without mention of bone loss should be coded as an amputation (Nature of Injury Code:

weeks after the incident [Anderson et al., 2010]. Eligible cases included amputations in which the injury incident occurred during 2007 – 2008 and involved workers 15 years or older employed in Massachusetts establishments, including the self-employed.

Data sources

Data from three sources - workers' compensation records, hospital administrative records, and SOII - were used for case ascertainment. MDPH entered into data use and confidentiality agreements with the three government agencies maintaining these records and obtained approval from the MDPH Institutional Review Board. As shown in Table I, the data sources differed in terms of populations covered, severity of injury captured, and data coding systems used. All sources were initially reviewed for work-related amputations with preliminary designation as probable or possible (see below). Additional information from medical records was collected for amputations ascertained using hospital administrative records. Subsequently, exclusion criteria were applied to arrive at the final set of work-related amputations.

Workers' compensation (WC) data

Almost all employers in Massachusetts are required to maintain workers' compensation insurance and submit reports of injuries and illnesses resulting in five or more lost workdays (starting on day of incident if injury occurs before noon) to the Massachusetts Department of Industrial Accidents (MDIA). The MDIA dataset of lost time claims includes employee name, address, gender, date of birth and occupation; employer name and address; date of injury; American National Standards Institute [ANSI, 1969] codes for nature of injury and affected body part; and a brief narrative description of how the injury occurred. ANSI codes are selected by the persons completing the reporting forms (e.g., employer, attorney, insurer, employee) from a list of codes provided on the back of the reporting form. Claims awarded cannot be distinguished from claims filed.

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031). An injury reported as an amputation involving a limb that did not involve bone loss should be coded as an avulsion (Nature of Injury code: 033).

ANSI Nature of Injury code 100 (amputation) and/or any variation of the words 'amputation', 'avulsion', 'deglove,' 'cut off', 'sever', 'detach', 'rip off', 'lost tip' in the incident narrative were used to search MDIA files for 2007-2009 to identify amputations with dates of injury during 2007-2008. The incident narrative for each record meeting the search criteria was reviewed. Records in which the narrative clearly indicated that the injury was not an amputation were excluded. Records with ANSI code 100 and/or information in the narrative that an amputation had occurred were defined as probable amputations. Remaining records (i.e. records with Other Nature of Injury codes and text suggestive of amputations) were defined as possible amputations. It was not possible to determine bone loss status of amputations involving tips of fingers or toes based on the WC records. North American Industry Classification (NAICs) codes and establishment size category were obtained from state and publically available data sources. Occupation was coded manually by trained MDPH coders according to the Standard Occupation Classification (SOC). Information about source of injury was abstracted from the incident narrative and coded according to OIICS. All amputations were assumed to be work-related.

Massachusetts Survey of Occupational Injuries and Illnesses

The Massachusetts Department of Labor Standards (DLS) collaborates with BLS to conduct the SOII in Massachusetts. Following BLS protocols, data from on-site OSHA logs and supplementary materials are collected from a sample of over 5,000 establishments annually (approximately 4% of the 130,000 establishments and 33% of the workforce statewide). Details on nature of injury, body part, source of injury/illness, event or exposure, and date of injury, as well as worker demographics (birth date, age, gender, race/ethnicity combined) are collected only for injuries or illnesses resulting in one or more lost workday (starting on the day after the incident) and are included in the *case and demographic* file. Nature, body part, source and event are coded according to OIICS by DLS staff. Also included is information about patient name,

occupation, employer name and address, and establishment size category. Industry and occupation are coded according to NAICS and SOC, respectively.

OIICS Nature of Injury codes for amputation (0310, 0311 or 0319) were used to identify amputations in the Massachusetts SOII case and demographic data for 2007 and 2008. All amputations so identified were considered probable amputations. The entire two year file of all MA SOII cases was retained for matching with other sources to allow for identification of amputations reported in SOII as other injuries.

Hospital Case Mix Data

The Massachusetts Division of Health Care Policy and Finance[2] maintains three separate datasets of hospital encounters in all non-federal acute care hospitals for purposes of rate setting, surveillance and research: inpatient hospitalizations (HD); outpatient observation stays (OOS) and emergency department (ED) visits. For any single hospital encounter, the datasets are mutually exclusive with a single case being recorded at the highest level of care (HD > OOS > ED). A single patient may have multiple encounters for the same injury over time and possibly at different hospitals. The data are collected on a federal fiscal year basis (October 1 – September 31); data for the full calendar year are available for surveillance purposes approximately 18 months after close of the calendar year.

Each HD record includes up to 15 clinical diagnoses and 15 procedures coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). Injury cases are also assigned External Cause of Injury codes (E-codes) at hospitals. Hospitals may also assign "V" codes – supplementary classifications of factors influencing health status. Records include a medical record number and information about patient demographics, (age, sex,

[2] Renamed the Center for Health Information and Access in 2012.

race, ethnicity and zip code of residence), zip code of employer and primary payer. They have neither patient nor employer names nor street addresses.

The OOS and ED datasets, though similar, have several notable differences. Both have fewer fields for diagnostic (up to 6) and procedure codes (up to 4); both have no employer zip codes. OOS data allow either CPT or ICD-9-CM codes to be used for procedures; and the ED data set has a short narrative text field to state reason for visit.

These three administrative datasets were merged for this analysis and are hereafter collectively referred to as Case Mix (CM) data. Nature of Injury codes for traumatic amputations (ICD-9 CM: 885-887, 895, 896, 897) and amputation procedure codes in any of the available diagnostic or procedure fields were used to identify probable amputations with dates of hospital encounter (admission for HD) in 2007-08. Several amputation-related diagnostic and procedure codes, such as stump complication (ICD-9-CM: 997.6) were used to identify possible amputations (see Supplemental Material, online only).

Probable and possible amputations with WC listed as primary payer, select E and V codes and/or key terms in the ED 'reason for visit' narratives (see Supplemental Material online only) were designated as likely work-related. All other traumatic amputations and probable amputations identified through procedure codes only with a primary diagnostic code of traumatic injury were designated as uncertain work-related. Probable amputations identified through procedure codes only with a primary diagnostic code of disease and no indication of work-relatedness were considered not work-related and excluded from further analysis. All possible amputations with no indication of work-relatedness were likewise excluded (Table II).

Medical records

MDPH has legal authority to collect medical records for select health conditions, including amputations, from Massachusetts hospitals [105 CMR 300.193]. Using medical record numbers, medical records were requested by mail from hospitals for all probable and possible amputations that were likely or uncertain work-related in the CM data to obtain patient and employer names and addresses needed to match cases with the other data sources and additional information to assess work-relatedness and bone loss. Over an 11 month period, records were obtained from hospitals or, abstracted on-site at the request of hospitals (3 hospitals) for 98% of the cases.

Based on medical record review, MDPH data abstractors made an assessment of work-relatedness (likely/uncertain/not work-related) independent of payer information. CM amputations were subsequently considered likely work-related if identified as such through either payer information (WC) *or* medical record review. Residents in occupational medicine assisted in review of clinical information to assign bone loss status (yes/no/indeterminate) to all cases considered likely or uncertain work-related.

Once medical records were obtained, personal identifiers were used to identify repeat encounters for the same injuries in the CM dataset and create an injury level CM file for matching with other data sources. Amputations clearly not work-related, those that occurred before the study period, and other injuries miscoded as amputations were excluded prior to matching.

Merging data sets and development of final multisource file

The full SOII file was merged with files of: 1) probable and possible WC amputations, and 2) probable and possible CM amputations, both likely and uncertain work-related, to identify matched cases using FRIL®v.2.1.4. FRIL is a software program that uses the probabilistic linkage approach to perform record linkage over large data sources which incorporates features, including Soundex, for maximizing the efficiency and accuracy of the linkages [Jurczyk et al., 2008; NARA, 2007]. Iterative deterministic and probabilistic linkages were carried out using personal (name, birth date, age, date of injury) and employer name (see Supplemental Materials,

online only), with extensive manual review of linked cases in which we considered additional variables including addresses and gender. Personal and employer identifiers of SOII-only cases were used to search the full MDIA file to identify WC amputations reported as other injuries.

A set of decision rules was developed and applied to the merged files to rule out amputations and create the final multisource file of work-related amputations with known or indeterminate bone loss. Major decision rules were as follows. Any case reported as: 1) an amputation in the SOII, and/or 2) a probable amputation in the WC, and/or 3) a probable amputation in CM file *and* likely work-related was retained *unless* there was specific medical record information ruling it out as a bone loss amputation. We excluded possible WC amputations that matched with SOII cases coded as other injuries. We also excluded CM-only amputations with uncertain work-relatedness, employed outside of Massachusetts, or with dates of injury incident prior to the study period.

Data analysis

Proportions of cases captured by data source were computed and frequency distributions of cases by demographic, injury and employment characteristics were compared across data sources using weighted SOII estimates rather than raw counts for these comparisons.

Comparison with SOII estimates

Not all work-related amputation cases are eligible for inclusion in the SOII case and demographic file. Each multisource case was categorized as SOII eligible, ineligible or unknown eligible considering both injury and worker eligibility. Eligible injuries included amputations resulting in one or more lost workday. All WC cases and all CM cases resulting in hospitalization or with amputations involving body parts other than fingers were assumed to meet this SOII lost time criterion. CM-only cases with any part of the fingers identified as the body part were considered unknown eligible on the basis of lost time. Eligible workers included those working in

establishments covered by the SOII. All WC and CM cases clearly involving federal or household workers, workers on small farms or the self- employed (all years) or state and municipal workers in 2007 were considered ineligible. WC and CM cases with insufficient information to determine whether the worker was employed in one of these categories were considered unknown eligible.

The count of multisource SOII eligible cases was compared to the published SOII estimate of amputation cases for the two-year period to generate a measure of the SOII *undercount*. Because some multisource SOII eligible amputations were reported as other injuries in the SOII, a *revised SOII estimate* was computed treating these "other injuries " as amputations and using SOII sample weights. The count of SOII eligible cases was compared to this *revised SOII estimate* to generate a measure that hereafter is referred to as the SOII *underreport*.

Additional analyses were carried out to assess the effect of making different assumptions about multisource cases with unknown SOII eligibility. Results of capture-recapture analyses of these data are reported elsewhere [Tak et al., this issue].

To assess whether published SOII findings were representative of all amputations eligible for inclusion the SOII, we compared the distribution of multisource SOII eligible cases by demographic, injury and employment characteristics with the distribution based on published SOII estimates. We also compared distributions of the published and revised SOII estimates.

Results

Counts of amputations meeting initial search criteria by data source and included in the final enumeration of work-related amputations are presented in Figure I. A total of 787 unique cases meeting the surveillance case definition were identified after matching and application of final decision rules. The largest percentage (82%) were ascertained through CM data, followed by WC (45%), and SOII (13%) (Table III). Of the 106 cases captured in the SOII data, 43 (41%) were reported as "other injuries" with the largest numbers reported as cuts/lacerations (24) and

crushings (5). Likewise 23 (7%) of the WC cases were reported in WC as other injuries. Notably, 406 (52%) of the unique cases were ascertained through CM records only. Of these, 321 were identified through ED records.

The SOII estimated number of work-related amputations in Massachusetts during the two year study period was 210 (95% CI: 158-262). The multisource count of 787 work-related amputations was 3.7 times higher than this estimate.

The distribution of cases by demographic, injury and employment characteristics by data source is presented in Table IV. The distribution of SOII cases in this table is based on the published SOII estimates. Age and gender distributions were largely similar across data sources. As expected, CM cases included a substantial fraction of self-employed (10%), and there were proportionately more serious cases (those involving body parts other than fingers or toes) among the WC and SOII cases. Missing race and ethnicity information in WC and SOII data sets precluded meaningful comparisons across data sources as did missing information on occupation among WC and CM cases. There was a high percentage of SOII estimated cases in manufacturing (54%) compared to WC (31%), and CM (24%). There was a low percentage of SOII estimated cases in smaller establishments (< 50 employees) compared to WC cases. Establishment size information was missing for over 40% of the CM cases.

Source of injury information was available for 86% of cases. The leading sources for all cases were machinery (31%) and saws (22%). Distributions by source were similar for WC and CM cases, whereas among SOII estimated cases, saws accounted for only 7% of the cases and machinery accounted for 46%.

SOII undercount

Of the 787 multisource cases, 406 were SOII eligible, 96 were ineligible, and 285 had unknown SOII eligibility. Comparison of multisource SOII cases with and SOII estimated cases is depicted in Figure II. The ratio of the multisource SOII eligible cases (406) to the SOII published estimate (210) was 1.93, yielding a minimum estimate of the undercount of 48% (95% CI: 36-61%). Of the 285 multisource cases with unknown SOII eligibility, the majority (n=189) were SOII eligible workers (employed in establishments covered by the SOII) but with insufficient information to determine lost time. Including all work-related amputations among SOII eligible workers regardless of lost time (n=595) produced an undercount estimate of 65% (95% CI: 56-73%).

As described, to assess "underreporting" we included amputations reported by employers but as other injuries in the SOII in generating a revised SOII estimate. When these "uncounted amputations" were taken into account using the *revised SOII estimate (310)*, the estimated underreport of clearly eligible cases was 24%. When all cases involving SOII eligible workers regardless of lost work-time (n=595) were included, the estimated underreport was 48%.

The distributions of multisource SOII eligible cases and published SOII estimated cases were similar with respect to gender, age and body part injured. (Absolute differences in percentages ranged from ±0.0 - 4.5%; data not shown). However, compared to multisource SOII eligible cases, proportionately more SOII estimated cases were employed in manufacturing (53% vs. 33%) and proportionately fewer were employed in establishments with less than 50 employees. (24% vs. 45%). (Table V). As shown in Table V, the distributions of published and revised SOII estimated cases by establishment characteristics were similar. They were likewise similar across demographic and worker characteristics. (Absolute differences in percentages ranged from ±0 - 5.8%; data not shown).

Discussion

In this study, we found that combining information from multiple data sources to enumerate work-related amputations in Massachusetts was feasible and provided useful, otherwise unavailable information to inform prevention efforts. Findings add to the evidence and understanding of undercounting in the SOII and provide insights about the challenges to implementing a multisource approach to surveillance of non-fatal occupational injuries nationally.

Multisource pilot

Given access to personal identifiers in the WC and SOII data, and in the medical records obtained for CM amputations, coupled with establishment and incident information, we were successful in merging information across the three data sources with a high degree of certainty about matched cases. Each of the three data sources used for case ascertainment had difference exclusions, and, as found in previous studies, the multisource approach identified many more work-related amputations than any single data source [Friedman et al, 2012; Largo and Rosenman, 2013]. The finding that over half of the 787 unique multisource cases (52%) were identified solely by CM records underscores the value of using health system data as a complement to the SOII and WC records more conventionally used for surveillance of work-related injuries and illnesses. Recent Danish and Canadian studies likewise highlight the added value of using hospital records to document work-related injuries [Fleming et al., 2014; Mustard et al., 2012]. The CM records offered the important advantage of providing information about amputations among workers covered by WC but not included in the WC lost time claim file, including workers with less serious amputations and potentially some workers with more serious injuries who may not have used the WC system to pay for their care [Azaroff et al, 2013]. CM records were also the only source of information on amputations among the self-employed. Additionally, CM records provided information on race and ethnicity, variables not available in WC records and commonly missing in SOII.

There were, however, a number of challenges in using CM records, the most time consuming of which was the need to collect medical records to obtain additional information necessary to merge the CM records with data from other sources, assess work-relatedness and SOII eligibility and characterize cases by industry and occupation, variables missing in the CM datasets. Another challenge was the high proportion of all CM encounters for work-related amputations that were repeat encounters for the same injury (15%), a factor important to consider when making simple count comparisons between hospital administrative data and information from other sources. Lack of specific information on work-relatedness, independent of payer source, not only in the CM file, but also in the medical records was another limitation.

Comparison with SOII estimates

Central goals of population-based surveillance are to describe the magnitude and distribution of public health problems, generating information to target and evaluate prevention efforts. In comparing two approaches to surveillance of an adverse health event, keys questions, therefore, are whether the two approaches provide similar information with respect to both these dimensions of the problem.

In this study, we found that the multisource count of work-related amputations in Massachusetts was 3.7 times the SOII estimated number of cases during the study period. In short, the multisource approach revealed a far larger problem. This difference was explained in part by SOII-ineligibility of some cases, such as the 8% self-employed, a well known gap in the official surveillance system. Yet, even when comparison between approaches was restricted to cases clearly eligible for the SOII, there were nearly twice as many multisource cases as the SOII estimate; and the minimum estimate of the undercount was 48% [95% CI: 36-61%].

An important finding in this study, however, was that many amputation cases were reported in the SOII as other injuries – thus these injuries were "reported" by employers, but not counted as amputations. Possible explanations include employers' lack of knowledge about the exact nature of injuries, delayed amputations following earlier injuries for which employers failed to update OSHA logs, or reporting or coding errors. When these "uncounted" amputations were taken into account using the revised SOII estimate, the estimated underreport of clearly eligible cases was 24%. Reporting of amputations as other injuries on the OSHA logs thus appeared to account for about half of the estimated undercount among clearly SOII eligible cases. A number of additional factors likely contributed to the undercount. Employer in the SOII sample may not have reported all amputations of which they had knowledge; employers may have been unfamiliar with record-keeping requirements, or they may not have been aware of injuries because workers did not report their injuries for any number of factors that can serve as barriers to worker reporting. There may also have been SOII sampling limitations.

Our estimated range of underreporting was on the lower end of previous estimates based on studies examining all work-related injuries and illnesses, [Rosenman et al., 2006; Boden and Ozonoff, 2008; Boden, this issue]. This was not unanticipated given the serious nature of amputations and comparatively straightforward attribution to work. Largo and Rosenman [2013], using multiple data sources to track work-related amputations in Michigan, estimated that SOII undercounted amputations (excluding those among the self-employed) by 57%, a finding fairly similar to our estimate of the eligible amputation undercount (48%). Friedman et al. [2012], using multiple data sources to track work-related amputations in Illinois, found a much higher congruence between multisource counts and SOII estimates, but he did not have access to data from all emergency departments.

As noted, in comparing different approaches to surveillance, it is important to assess whether the approaches yield similar information about not only the overall magnitude but also the

distribution of the problem. While different approaches to surveillance may provide different estimates of magnitude, as they did in this study, they may still provide similar views of the distribution and therefore identify similar prevention priorities. Unfortunately, our ability to compare the distribution of SOII estimated and multisource amputations with respect to worker, employer, injury and incident characteristics was limited due to the small number of amputations in the SOII sample, the lack of available standard errors for the SOII estimates and missing information on key variables in different data sources. Nonetheless, our findings were suggestive of several differences that raise important questions about representativeness of the SOII estimates that should be further investigated, most notably the high proportion of SOII estimated amputations in manufacturing compared to multisource cases. There also appeared to be proportionately fewer SOII estimated cases in establishments less with less than 50 employees compared to multisource SOII eligible cases. This finding, albeit limited by missing information, is consistent with several previous studies that have found that undercounting is greater in small establishments [Mendeloff et al.; 2006; Dong et al., 2011]. Possible factors believed to vary by industry and influence employer record-keeping include misclassification of workers as independent contractors, use of temporary workers, use of injury rates to qualify for contracts, and employer lack of knowledge about completing OSHA logs, which may be a particular concern among smaller employers who do not routinely complete these logs unless selected by BLS to participate in the SOII. Injury severity may also vary by industry and could also influence these patterns.

Strength and limitations

A strength of this study was the use of SOII records in addition to WC and hospital administrative data, and the inclusion of more comprehensive ED data than used in other multisource studies of work-related amputations [Largo and Rosenman, 2013; Friedman et al., 2012]. The collection and clinician review of medical records for almost all CM cases was a strength as was the systematic approach to classifying multisource cases according to bone loss

and SOII eligibility status for comparison with SOII estimates. The approach of generating a revised SOII estimate allowed for distinguishing between undercounting in the SOII and employer failure to record the injury at all on OSHA logs (underreporting), an important distinction when examining the extent to which SOII captures specific work-related conditions.

This study had many limitations, especially the difficulty in defining amputations consistently across datasets. The issue of bone loss and the evolution of injuries over the course of time (initial crushing injury that subsequently becomes an amputation) were problematic. We addressed this as best we could by using the best available information for each case, and applying a standard set of decision rules. This difficulty in defining amputations highlighted the fundamental challenge of comparing non-clinical information reported by employers and clinical information from hospitals.

Missing information on other key variables was also problematic, not only for comparing work-related amputations by case characteristics across data sources as described, but also for case ascertainment and determination of SOII eligibility. In the SOII file, information was mostly complete, with the exception of information about race/ethnicity, which is not a mandatory reporting element. However, WC and CM are both administrative data sources not intentionally designed for occupational health surveillance. Key information such as and work-relatedness (CM), occupation (CM and WC), industry (CM) and lost time (CM) was often missing. With respect to case ascertainment, our general approach was to handle missing information conservatively, i.e., exclude amputations that we could not reasonably and confidently assume should be included. For example, we excluded the over 200 unsure work-related CM amputations from the final multisource enumeration. With respect to SOII eligibility in our analysis of the SOII undercount, we computed a range of estimates including a minimum estimate limiting cases to those with known SOII eligibility. It is also possible that some of the WC and SOII cases for which we did not have confirmatory medical records were not amputations. However, we do not

believe this to be a substantial concern as all SOII reported amputations for which we had medical records and 92% of WC cases with medical records met the surveillance case definition. Additionally, our methods did not allow us to identify cases treated in settings other than hospitals, such as urgent care centers, or in out-of-state hospitals, and captured by neither SOII nor WC. For this reason alone, the final multisource count is likely an underestimate of the true burden of work-related amputations in Massachusetts.

Amputations were chosen for this surveillance research study because it was assumed that, compared to other work-related conditions with more complex etiologies, work-related amputations would be comparatively straightforward to document. While we experienced some challenges in defining amputations, this assumption still holds and the specific findings presented here cannot necessarily be generalized to other work-related injuries and illnesses.

Generalizability of these multisource surveillance methods to national surveillance

While these findings are limited to one health condition in one state, they suggest that multisource surveillance can substantially enhance our understanding of the magnitude and distribution of work-related injuries and illnesses. Multisource approaches that include hospital administrative records can fill well known gaps in the SOII by including the self-employed and other excluded populations, provide information on data elements not available in any one data source, and shed light on the magnitude and distribution of the SOII undercount. Our experience, however, also suggests that a surveillance system for all nonfatal work-related conditions that would attempt to collect comparable data from all states using multiple data sources, similar to CFOI, is not currently feasible. The most challenging barrier is lack of comparability of data sources across states. Limited data access and lack of timeliness are also obstacles.

A significant barrier is the fact that multisource surveillance, as implemented in this and other similar studies, relies heavily on WC data, either directly through access to the claims or

indirectly by using payment information in hospital records to identify probable cases. There are widely recognized and substantial differences between WC laws and WC data collection systems across the states that limit data comparability [Sengupta et al., 2012; NIOSH, 2013; NIOSH, 2014]. Lack of comparability is more likely for illnesses, which may not be compensated in all states, and less serious injuries, as waiting periods for lost wage payments vary substantially across states. We also relied heavily on hospital electronic datasets for case ascertainment. While all states have inpatient hospital datasets, outpatient datasets are not in place in all states [Barrett and Steiner, 2013]. Variation in states laws governing data access and data sharing between agencies is likewise a barrier. While in theory these differences are not insurmountable, they remain practical obstacles in the near future.

Timeliness, defined as time between the surveillance period end and surveillance report, is impacted by delays in initial access to data sources as well as the time involved in processing the data. In this study, the delay in access to the CM data was a significant barrier to timely release of surveillance findings. Collecting medical records from over 80 hospitals also proved to be highly time consuming taking almost 12 months. If data collection is conducted routinely, the delays can be substantially reduced [Largo and Rosenman, 2013]. Alternatively, if public health regulations required active reporting of work-related conditions with personal and employer identifiers, as they do in Michigan, it may not be necessary to follow-back to hospitals for medical records. This would necessitate regulatory changes across the states. Changes in national policy, such as the current proposal to promote inclusion of industry and occupation codes in the Uniform Bill [Taylor and Frey, 2013], may provide new opportunities in the states in the long run. The ongoing effort to incorporate occupational information in electronic health records may likewise open up new long-term opportunities for more efficient data collection in the future [IOM, 2011; CSTE, 2012].

Despite the challenges in implementing multisource surveillance of work-related health conditions nationally, we believe that it is extremely useful at the state level for both case-based and population based surveillance to inform intervention activities. Such state level efforts conducted on an ongoing basis can fill surveillance gaps and contribute significantly to our understanding of the national burden. It will be more important for some health conditions than others, and the choice of surveillance targets should reflect a combination of state and national priorities for protecting workers' health [CSTE, 2001].

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TABLES

Table I. Attributes of data sources used for multisource surveillance of work-related amputations, Massachusetts, 2007-08

Attribute	Data Source		
	Workers' compensation records (WC)	Hospital administrative (Case Mix) records[a] (CM)	Survey of Occupational Injuries and Illnesses (SOII)
Data type (N records)	Census (N=91,283)	Census (N= ~7 million)	Sample (n= ~17,700)
Scope/ injury severity	Lost wage claims filed for injuries resulting ≥5 lost workdays	Discharges from acute care, non-federal hospitals	Employer reported cases with ≥I lost workday
Injury/illness coding system	ANSI	ICD-9 and CPT	OIICS
Excluded populations	Police, firefighters, the military, and federal government, maritime, railroad, and part time household workers[b] and the self-employed	None	The military, federal government, small farm, and household workers, state and municipal workers (2007 only) and the self-employed

[a] Includes data from three hospital administrative datasets: Inpatient hospitalizations, Outpatient observation stays, and Emergency department visits.

[b] Some of these groups are covered under other compensation programs.

ANSI: American National Standards Institute
ICD-9: International Classification of Disease, 9th revision
CPT: Current Procedural Terminology codes
OIICS: Bureau of Labor Statistics, Occupational Injury and Illness Classification System

Table II. Initial designation of work-relatedness of probable and possible[a] amputations identified using Case Mix records

Amputation group	Initial work-relatedness designation
Probable and possible amputations with an indication of work-relatedness: Workers' Compensation listed as primary payer, and/or select E and V codes[b], and/or key terms in the ED "reason for visit" free text field[c]	Likely work-related
Probable amputations identified through diagnostic codes for traumatic amputations, with no indication of work-relatedness	Uncertain work-related
Probable amputations identified through procedure codes only, with a primary diagnostic code of injury to a limb or digit and with no indication of work-relatedness	Uncertain work-related
Probable amputations identified through procedure codes only, with a primary diagnostic code of disease and no indication of work-relatedness	Not work-related
Possible amputations with no indication of work-relatedness	Not-work-related

E-code: Code for external cause of injury
V-code: Code for factor influencing health status or contact with health services
ED: Emergency department visit data set
[a] See Supplemental Materials, online only, for list of diagnostic and procedure codes used to define possible and probable

amputations.
[b] E800-E807 (with 4th digit of 0); E830-E838 (with 4th digit of 6); E850-845 (with 4th digit of 2 or 8); E849.3 (industrial place or premise); V26.1;V71.3 (see Supplemental Materials, online only).
[c] All variations of the following words: work, work injury, work-related.

Table III. Number and Percent of Work-Related Amputations* Captured by Data Source**, Massachusetts 2007 - 2008

Data Source	N	(N)[a]	%
CM	646[b]		82.1
WC	351		44.6
SOII	106	(63)	13.4
TOTAL	787		100.0
SOII CM WC	47	(34)	6.0
SOII CM	24	(3)	3.1
SOII WC	29	(20)	3.7
WC CM	169		21.5
CM-only	406		51.6
WC-only	106		13.5
SOII-only	6	(6)	0.8

SOII, Survey of Occupational Injuries and Illnesses; CM, hospital case mix; WC, workers' compensation.
* Includes amputations with known (76%) and indeterminate (24%) bone loss.
** Numbers of SOII cases reported here are raw numbers, not weighted estimates.
[a] Numbers in parentheses are the numbers of SOII cases reported as amputations in SOII.
[b] Seventy-eight percent of the CM cases had workers' compensation recorded as the primary payer.

Table IV. Distribution of work-related amputations[a] by data source and by worker, injury, and employment characteristics, Massachusetts, 2007 - 08

		CM			Published SOII
	All Sources % (N = 787)	All % (N = 646)	CM-Only[b] % (N = 406)	WC % (N = 351)	estimate % (n = 210)
Worker characteristics					
Gender					
Female	8.3	6.5	6.7	10.3	5.1
Male	91.2	93.5	93.4	89.2	93.9
Unknown	0.5	0.0	0.0	0.6	1.0
Age					
<18 years	0.4	0.3	0.3	0.6	- -
18-24	13.6	12.9	10.8	16.5	11.8
25-44	43.5	43.6	41.6	48.4	52.3
45-64	38.6	39.8	43.3	31.7	33.3
65+	3.2	3.4	3.9	2.3	2.6
Unknown	0.6	0.0	0.0	0.0	- -
Race/ethnicity					
White Non-Hispanic	60.2	70.9	74.9	43.9	47.7
Black Non-Hispanic	5.1	5.6	3.0	7.4	9.0
Hispanic	12.2	14.6	13.3	10.5	10.9

Other	5.0	5.7	5.7	4.0	9.6
Unknown	17.5	3.3	3.2	34.2	22.8
Injury characteristics					
Body part					
Finger	90.2	90.9	94.8	86.0	89.5
Other upper extremity	2.0	1.7	0.5	3.7	8.4
Toe	3.3	3.4	3.9	2.3	1.1
Other lower extremity	*1.9*	2.2	0.7	2.9	1.1
Other[c]	0.6	0.1	0.0	1.1	- -
Unknown	1.9	1.7	0.0	4.0	- -
Employment characteristics					
Employment type					
Wage/salary					
Public	4.7	4.2	3.2	6.5	- -
Private	70.0	65.2	48.3	92.9	100.0
Self-employed	8.4	10.1	15.8	0.6	0.0
Unknown	16.9	20.6	32.8	0.0	- -
Occupation (SOC)					
Management (11)	1.7	1.4	1.0	2.3	3.4
Food preparation and serving related (35)	2.7	1.4	0.7	4.0	5.3
Building and grounds cleaning and maintenance (37)	4.7	4.8	4.2	5.7	- -
Construction and extraction (47)	14.9	17.0	19.0	10.0	21.1
Installation, maintenance and repair (49)	4.7	5.0	3.0	6.6	8.7
Production (51)	14.9	13.6	6.4	22.5	47.3
Transportation and material moving (53)	7.0	7.1	3.4	10.8	11.0
Other[d]	2.9	2.2	1.5	4.0	- -
Unknown	46.6	47.5	60.8	34.2	- -
Industry sector (NAICS)					
Agriculture, forestry, fishing, and hunting (11)	1.4	1.7	2.2	0.3	- -
Construction (23)	20.6	23.2	23.6	17.4	25.9
Manufacturing (31-33)	24.3	23.7	16.7	30.5	52.7
Wholesale/retail trade (42, 44-45)	8.6	7.9	7.9	10.0	4.6
Transportation and warehousing (48-49)	1.9	2.0	2.0	1.7	2.1
Administrative and support and waste management and remediation services (56)	7.2	6.3	5.7	9.7	3.0
Healthcare and social assistance (62)	2.2	1.7	1.0	2.8	3.5
Accommodation and food services (72)	3.0	1.9	2.0	4.3	1.7
Public administration (92)	3.3	2.9	2.7	4.3	- -
Other services (except public administration) (81)[e]	2.4	2.5	2.2	2.8	- -
Other[f]	7.1	5.1	4.4	10.3	2.0
Unclassifiable (99)	16.1	19.2	28.3	3.4	4.6
Unknown	1.8	1.9	1.2	2.6	- -
Establishment size					
Less than 10 employees	15.5	16.6	15.3	17.1	- -
10—49	20.6	19.5	14.5	28.2	23.9
50—250	18.7	16.7	9.9	25.6	59.1
250 +	7.4	5.7	3.2	10.5	17.1
Unknown	37.9	41.5	57.1	18.5	- -

CM: Hospital Case Mix
WC: Workers' Compensation
SOII: Survey of Occupational Injuries and Illnesses
SOC: Standard Occupational Classification
NAICS: North American Industry Classification system
"- -" indicates the estimated percentage (%) is less than one.

[a] Includes amputations with known (76%) and indeterminate (24%) bone loss.
[b] Includes cases identified solely through hospital administrative records and not captured by other data sources.
[c] Includes cases reported with multiple body parts and 1 case with a miscoded body part.
[d] Includes architecture and engineering; education, training, and library; healthcare support; protective services; personal care and services; sales and related; office and administrative support; and farming, fishing, and forestry.
[e] Includes repair and maintenance; personal and laundry services; religious, grant making, civic, professional, and similar orgs.; and private households.
[f] Includes: mining, quarrying, and oil and gas extraction; utilities; information; finance and insurance; real estate, rental and leasing; professional, scientific, and technical services; management of companies and enterprises; educational services; and arts, entertainment, and recreation.

Table V. Distributions of multisource work-related amputations eligible for inclusion in the SOII and SOII estimates of amputations, by industry sector and establishment size, Massachusetts, 2007 – 08

	Multisource SOII eligible cases % (N=406)	Published SOII estimate % (n=210)	Revised SOII estimate % (n=310)[a]
Industry sector (NAICS)			
Agriculture, forestry, fishing (11)	0.7	- -	1.9
Construction (23)	18.0	25.9	20.3
Manufacturing (31-33)	33.0	52.7	54.2
Wholesale/retail trade (42, 44-45)	10.3	4.6	11.3
Transportation and warehousing (48-49)	2.0	2.1	- -
Administrative support and waste management (56)	8.4	3.0	1.9
Healthcare and social assistance (62)	3.4	3.5	3.0
Accommodation and food services (72)	4.2	1.7	1.9
Public Administration (92)	1.2	- -	- -
Other services (81)	3.0	- -	- -
Other	8.4	2.0	1.7
Unclassifiable (99) / unknown	7.4	4.6	3.1
Establishment size			
Less than 10 employees	17.0	- -	- -
10-49 employees	27.6	23.9	20.9
50-250 employees	27.6	59.1	63.5
250+ employees	11.3	17.1	15.7
Unknown	16.5	- -	- -

SOII: Survey of Occupational Injuries and Illnesses
NAICS: North American Industry Classification System
"- -" indicates the estimated percentage (%) is less than one.

[a] Revised SOII estimate computed including amputation cases reported in SOII as other injuries and applying SOII sample weights.

Supplemental Materials

SI. Table 1. Diagnostic and procedure codes [1,2] used to identify probable and possible amputations in the Hospital Administrative (Case Mix) Records

ICD-9 CM diagnostic codes (probable):
885 – traumatic amp of thumb (complete, partial)
886 – traumatic amp of other finger(s) (complete, partial)
887 - traumatic amp of arm & hand (complete, partial)
895 - traumatic amp of toe(s) (complete, partial)
896 – traumatic amp of foot (complete, partial)
897 – traumatic amp of leg(s) (complete, partial)

ICD-9 CM procedure codes (probable):
84.0 – 84.09 Amputation of upper limb
84.1-84.19 Amputation of lower limb
84.91 Amputation, NOS
84.2 – 84.29 Reattachment of extremity

CPT procedure codes[3] (probable):11752 23900 23920 23921 24900 24920 24925 24930 24931 24940 25900 25905 25907 25909 25915 25920 25922 25924 25927 25929 25931 26910 26951 26952 27290 27295 27590 27591 27592 27594 27596 27598 27880 27881 27882 27884 27886 27888 27889 28800 28805 28810 28820 28825 54120 54125 54130 54135 69110 69120

ICD-9 CM diagnostic codes (possible):
997.6 Amputation stump complication (excludes txt for current traumatic amp & phantom limb syndrome)
905.9 Late effect of traumatic amputation
V49.6 Upper limb amputation status
V49.7 Lower limb amputation status

ICD-9 CM procedure codes (possible):
84.3 Amputation stump revision
84.40-84.48 Prosthetic limb device (fitting or implanting)

CPT procedure codes[3] (possible)
20802 20805 20808 20816 20822 20824 20827 20838 24935

[1] Generic ICD-9-CM Hospital Version 2008 (vols. 1-3), Channing Publishing, LTD., 2007; Current Procedural Terminology (CPT) 2001, American Medical Association, 2000.
[2] Current Procedural Terminology (CPT) Professional Edition 2001, American Medical Association, 2000.
[3] CPT procedure codes available only in the Outpatient Observation Stay visit data set (OOS).

SI Table 2. Descriptions of ICD-9 CM External Cause of Injury (E-codes) and Supplemental information (V- codes) reported in Hospital Administrative (Case Mix) data that were considered as indicators that the amputation occurred at work

E-code	Code Description
E 800-E807 (with 4th digit of 0)	Injury sustained by an employee in a railway accident/incident
E830-E838 (with 4th digit of 6)	Injury sustained by a longshoreman (docker/stevedore) in a watercraft or water transport accident/incident
E840-E845 (with 4th digit of 2 or 8)	Injury sustained by the flight or ground crew in an aircraft or air transport accident/incident
E 849.3	Denotes that the injury occurred at an industrial place or premise
V-code	
V62.1	Adverse effects of work environment
V71.3	Observation following accident at work

SI Table 3. Data elements used in the linkage of cases from three sources, Workers' Compensation (WC), Hospital Administrative (Case Mix) and Related Medical Records, and Survey of Occupational Injuries and Illnesses (SOII)	
Employee (worker) information	
	First name of employee/worker
	Last name
	Abbreviated name (first letter of first name + first 4 letters of last name)
	Soundex of last name (using first 4 letters)
	Date of birth
	Age
	Gender[a]
	Worker address (WC & Case Mix/medical record only)[a]
Injury/illness (medical) information	
	Date of injury and Admission date (Case Mix/medical record only)
Employer information	
	Employer Name
	Abbreviated employer name (first 6 letters)
	Employer Address (street, city/town, zipcode) [a]

[a] Denotes data elements that were used only for manual review and verification of matched cases.

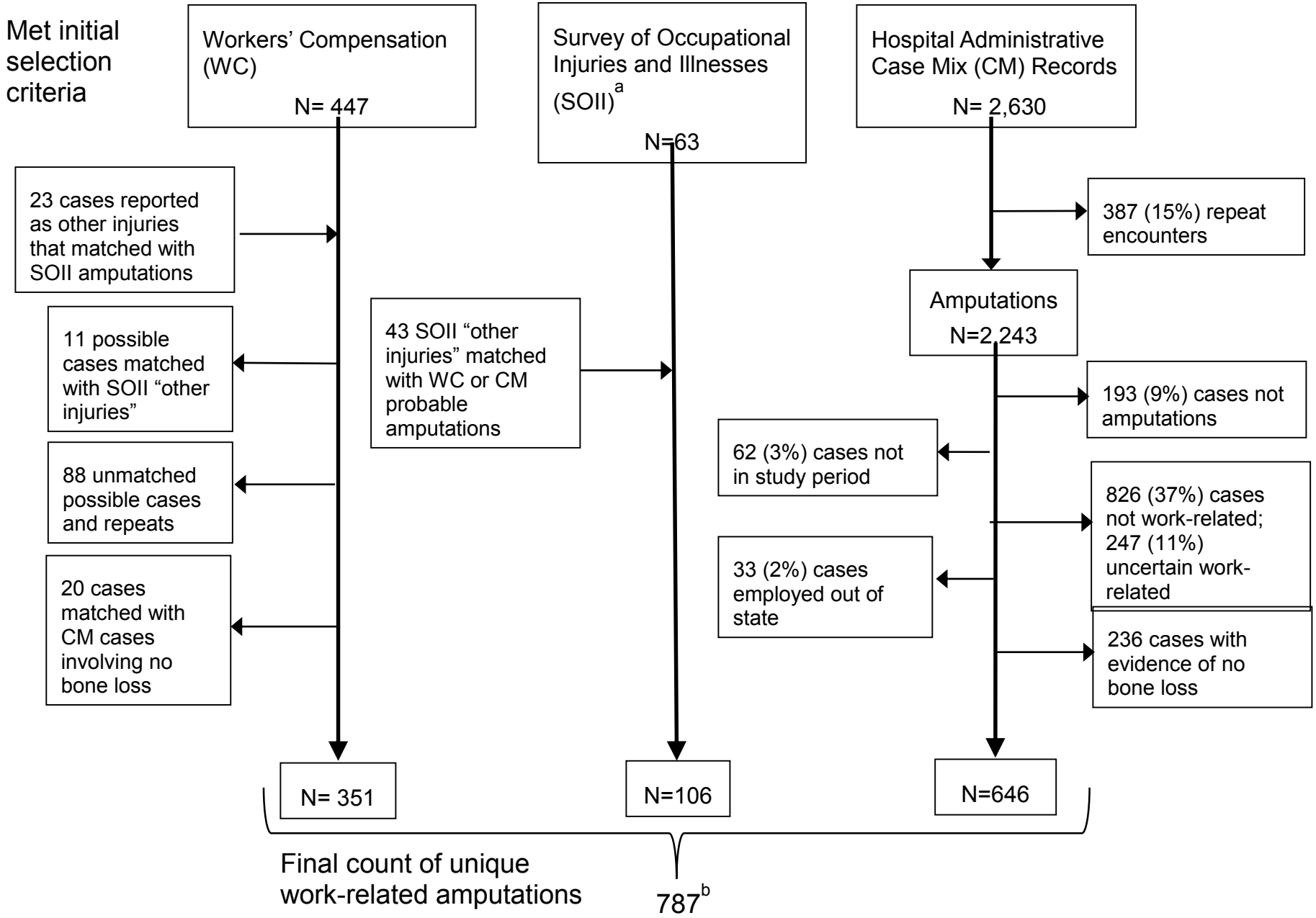

FIGURE 1. Flow Diagram of amputation cases and encounters meeting initial selection criteria to inclusion in the final file of work-related amputations.

[a] Numbers of SOII cases are raw counts, not weighted estimates.

[b] Includes amputations with known (76%) and indeterminate (24%) bone loss.

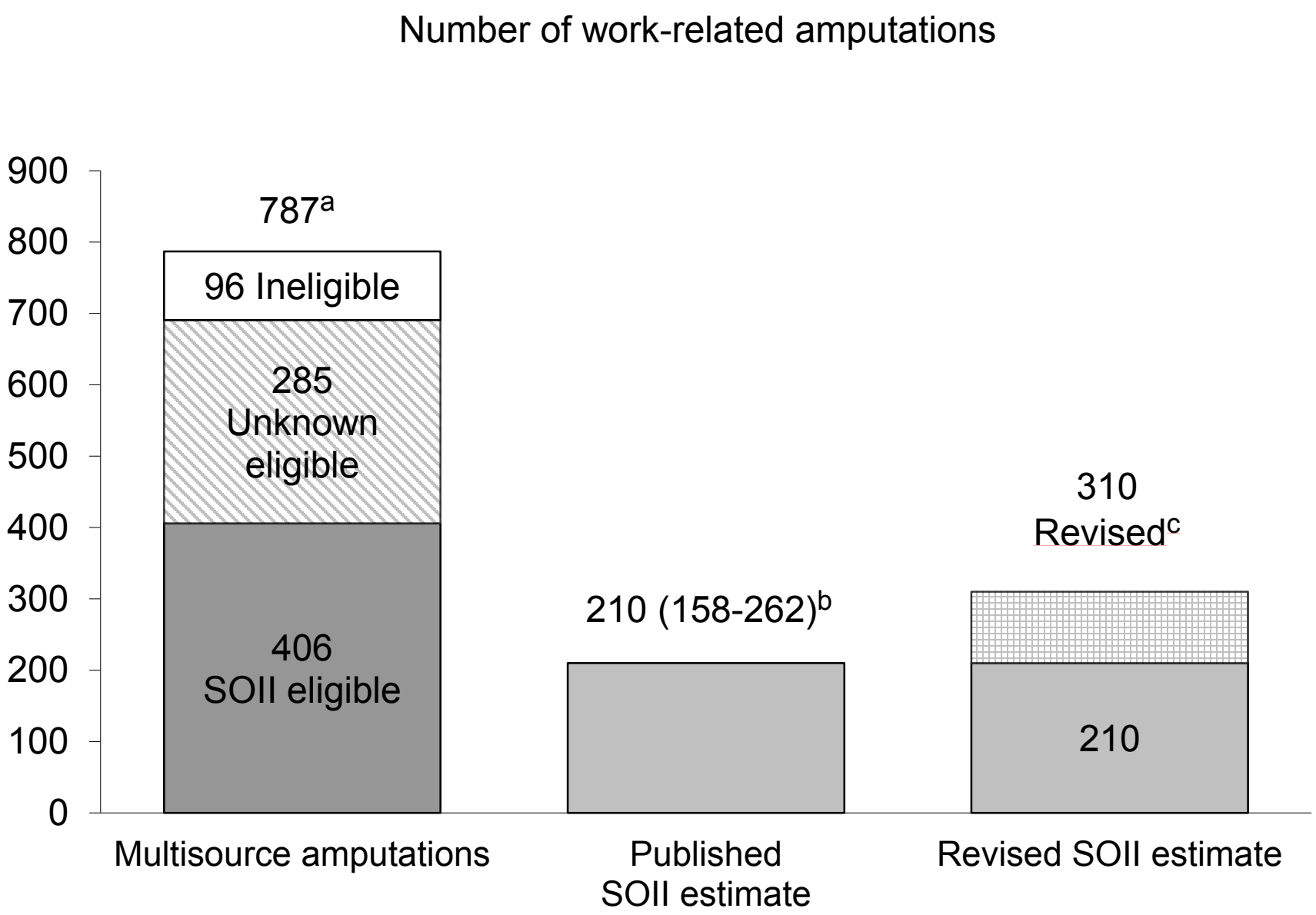

Figure 2. Number of multisource work-related amputations eligible for inclusion in the SOII compared to published and revised SOII estimates of amputations, Massachusetts, 2007 – 2008.

[a] Includes amputations with known (76%) and indeterminate (24%) bone loss.

[b] Range in parentheses is the 95% confidence interval for the SOII estimate.

[c] Revised SOII estimate (310) computed including amputations reported as *other injuries such as cuts/lacerations* on OSHA logs and in SOII.