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RESEARCH ARTICLE

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Evaluation of the characteristics of injured workers and employer compliance with OSHA's reporting requirement for work-related amputations

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Abstract

Introduction: In 2014, the Federal Occupational Safety and Health Administration (OSHA) enacted a standard requiring employers to report work-related amputations to OSHA within 24 hours. We studied the characteristics of the injured workers and employer compliance with the regulation in Michigan.

Methods: Two independent data sets were used to compare work-related amputations from 2016 to 2018: employer reports to OSHA and the Michigan Multi-Source Injury and Illness Surveillance System (MMSIISS). We deterministically linked employer reports to OSHA with the MMSIISS by employee name, employer name, date, and type of amputation.

Results: We identified 1366 work-related amputations from 2016 to 2018; 575 were reported by employers to OSHA and 1153 were reported by hospitals to the MMSIISS. An overlap of 362 workers were reported in both systems, while 213 workers were only reported by employers to OSHA and 791 workers were only reported by hospitals. Employer compliance with the regulation was 42.1%. Employer compliance with reporting was significantly less in: agriculture, forestry, fishing, and hunting (14.6%); construction (27.4%); retail trade (20.7%); arts, entertainment, and recreation (7.7%); accommodation and food services (13.0%); and other services (27.0%). Large employers and unionized employers were significantly more likely (67.9% and 92.7%, respectively) and small employers were significantly less likely (18.2%) to comply with the reporting rule. Enforcement inspections at 327 workplaces resulted in 403 violations; of those, 179 (54.7%) employers had not corrected the amputation hazard before the time of inspection.

Discussion: Michigan employers reported less than half of the work-related amputations required by OSHA's reporting regulation. Noncompliance was greatest in small employers, and agriculture, forestry, fishing, and hunting; construction; arts, entertainment, and recreation; accommodation and food services; and retail and other service industries. Inspections found that over half of the employers had not corrected

the hazard that caused the amputation at the time of the inspection's initial opening date; in these cases, abatement of any hazards identified would have occurred after the inspection. Improved compliance in employer reporting of work-related amputations will identify hazards posing a high risk of recurrence of injury to other workers from the same injury source. Greater compliance can also help target safety-related preventive and intervention efforts in industries that might otherwise be overlooked.

KEYWORDS

employer reporting, occupational injury reporting, severe injury, workplace safety, work-related amputation

1 | INTRODUCTION

Work-related amputations are preventable. They generate a life-long burden at home and in the workplace. Identifying individuals with work-related amputations and conducting inspections at their workplaces is useful to understand workplaces that are at high risk for amputations and identify workplace safety measures that are needed to prevent co-workers from sustaining similar injuries.

In Illinois from 2000 to 2007, researchers identified an overlap of only 653 of 3984 cases of work-related amputations across three data sources—hospital discharge data, a trauma registry and workers' compensation—with only eight cases found across all three sources.[1] Based on their findings they recommended that the Occupational Safety and Health Administration (OSHA) establish a mandatory reporting rule for work-related amputations within 24 h of the event so that OSHA could more fully identify and inspect employers where co-workers might still be at risk from the hazard that was associated with the amputation.[1]

In 2014, Federal OSHA implemented a new reporting requirement for work-related amputations (29 Code of Federal Regulations 1904.39(a)(2)). All state-plan and hybrid state-plan (cover state and local workers only) OSHA programs were required to adopt the new requirement. Federal-run, state-run, and hybrid OSHA programs have the same mission to support workplace safety and health; state-run and hybrid OSHA programs must be at least as comprehensive as the Federal program and may adopt additional safety and health programs or regulations not required by Federal OSHA. In 2015 Michigan OSHA (MIOSHA), a state-plan state, adopted the reporting requirement. Before this, employers were only required to report inpatient hospitalizations of three or more employees.

One year after the reporting requirement went into effect, Federal OSHA conducted an evaluation of employer reporting of work-related amputations from Federal OSHA states by examining 2644 amputations and inspecting 58% of the employers associated with the amputations.[2] OSHA concluded that in most cases, they would never have identified the hazards if the reporting requirement had not been in effect. Despite the reporting requirement, OSHA estimated that employers underreported severe injuries including amputations by 50% based on national data in comparison with workers' compensation data.[2]

In a recent manuscript, we examined employer compliance with another aspect of the OSHA reporting requirement that requires employers to report all acute, severe injuries and illnesses resulting in an overnight inpatient hospitalization and found that the employer failed to report 56.4% of the work-related hospitalizations.[3] Other studies have found that employers vary greatly in their compliance with occupational injury and illness regulations involving reporting and recordkeeping.[4,5] Researchers in Washington found that 90% of employers failed to correctly record work-related injuries in the Bureau of Labor Statistics Survey of Occupational Injuries and Illnesses (BLS SOII).[6] Another study found that the reasons for incorrect or incomplete reporting included business practices geared to maintaining low injury rates on paper, poor recordkeeping, and lack of understanding of reporting requirements.[7] An evaluation of a Federal OSHA National Emphasis Program for Recordkeeping found violations at approximately half of the employers inspected.[8] Interviews with employees during these inspections found the top reasons they did not report an injury to their employer included fear of reprisal and potential disciplinary action by their employer as a result of their injury.[8] A recent review of the literature that only examined *employee* underreporting of injuries affirmed the barriers include fear of the consequences for reporting to their employer, being unaware of reporting requirements, unwillingness to fill out paperwork, and perceptions that the injury is not sufficiently severe to warrant reporting.[9]

This manuscript examines the characteristics of workers who sustained a work-related amputation. We compare amputations submitted directly by employers to the state OSHA plan in compliance with the reporting requirement to hospital-reported cases, which are regularly submitted to the state as part of Michigan's Multi-Source Injury and Illness Surveillance System (MMSIISS). We also examine the characteristics of the employers inspected by OSHA enforcement where the amputations occurred. There have been no previous evaluations of the reporting requirement for amputations using medical records from hospitals independent of employer reporting to OSHA or workers' compensation data.

2 | METHODS

In 2014, Federal OSHA instituted a national employer reporting regulation; on September 1, 2015, MIOSHA as required by Federal OSHA adopted a similar regulation that requires employers to report any employee who sustains a work-related amputation within 24 h to a special hotline or online portal. In a recent manuscript, we described which employers are under OSHA jurisdiction and therefore required to comply with the reporting requirement.[3] The authority to require employer reporting of amputations was based on MIOSHA Administrative Standard Part 11, Recording and Reporting of Occupational Injuries and Illnesses. We have previously described the extensive outreach efforts by MIOSHA that were made to employers about the new reporting requirement.[3]

Separate from this employer-reporting requirement, Michigan has maintained a multisource surveillance system, the MMSIISS, for work-related injuries including amputations, based on a regulation adopted in 2010 for traumatic injuries, Michigan Public Health Code Article 369, R325.301-306, P.A. 1978. All 134 Michigan hospitals report work-related hospital visits, including inpatient, outpatient, and emergency department encounters including amputations to the MMSIISS on a quarterly basis. All medical encounters in this manuscript involved hospital-based care. Inpatient hospital visits were defined as a formal admission to the inpatient service of a hospital, not just an overnight observation. Outpatient visits were most commonly an emergency department visit, but less commonly were a visit to a hospital-based outpatient clinic. In the compilation of Michigan hospital data, emergency department visits are considered a subcategory of outpatient visits. We have previously described how hospitals report all workers (e.g., self-employed, miners, railroad workers) regardless of whether the employer is regulated and required to report to OSHA.[3] Hospitals reported any inpatient, outpatient, and emergency department visit for anyone aged 14–70 years of age with an amputation, which was defined as having a primary or any secondary ICD-10 discharge code of or within the subcategories of S48, S58, S68, S78, S88, or S98, regardless of payer source; the MMSIISS program then reviewed the medical records for all patients obtained. We excluded hospital-reported amputations of workers who were either self-employed or who worked in industries not regulated by OSHA, and hospital visits that occurred greater than 24 h after the amputation. We abstracted the first hospital encounter for each worker. Each worker was counted once even if they sustained multiple amputations of digits or other body parts.

We deterministically linked the 2016–2018 employer reports to OSHA with the hospital reports to the MMSIISS by employee name, employer name, date, and type of amputation. We have previously described the minor nuances of miscoding between the two systems regarding the elements used to link cases.[3] All linked cases were validated by evaluating the demographics, amputation type, and industry characteristics on cases reported by employers to OSHA and the medical records provided by hospitals to the MMSIISS. All work-related amputation matches were clearly true matches.

Additionally, we searched the Michigan Workers' Disability Compensation Agency (WDCA) database of paid claims for 2016–2018 to identify which cases reported by employers to OSHA or reported by hospitals to the MMSIISS received a workers' compensation award for their amputation. The workers' compensation file contained paid claims for wage replacement defined as lost work time of 7 or more consecutive days, which included weekend days, and also included all paid claims for specific loss, defined as amputations, loss of vision, total loss of hearing, and death. Specific loss claims were included in the WDCA database regardless of the number of lost workdays.

Both employer reports to OSHA and hospital reports to the MMSIISS used the same definition of a work-related amputation, which included loss of a limb or other external body part, either partial or complete, with or without bone loss, medical amputations in cases where repair is not possible, and reamputations of parts that had been reattached. We used the narrative in the employer reports to OSHA and the description of the amputation in the hospital medical records to determine the type of amputation.

Both systems collected the date of injury, injured employee name, employer name, and a description of the amputation type and body part. Hospitals collected additional data that were not collected in the OSHA system: age, gender; race; Hispanic ethnicity; date of admission or visit, and date of discharge, if an inpatient visit. The OSHA employer reporting system does not collect hospital name or other medical facility where the worker sought care. Even though the OSHA employer system does not collect gender, it could largely be imputed based on the name of the individual or the pronoun used in the narrative in the report by an employer to OSHA. We attempted to contact workers in the MMSIISS where the medical record did not indicate an employer name; however, not all employers could be identified. Letters were sent to 184 individuals with an amputation where the medical record did not list the employer's name, or more information on how the amputation occurred was needed to clarify whether an OSHA inspection might be indicated. Among the 19 who responded, 17 reported their amputation was work-related and they had reported it to their employer; one of the other two indicated they were performing personal tasks and the other indicated the amputation had occurred many years prior.

For workers who required inpatient hospitalization, length of stay (LOS) for workers reported by hospitals to the MMSIISS was calculated based on date of admission to date of discharge. A North American Industry Classification System (NAICS) code was assigned to each employer. We have previously described our methods to classify NAICS codes for each employer,[3] and added a new source since that time, the Dun and Bradstreet online employer search engine. Employer size was classified as small (1–10 employees), medium (11–249 employees), and large (250+ employees). Employer size was mostly identified through prior information collected at the MMSIISS surveillance center on industries associated with other work-related conditions in the state and supplemented for 10% of the cohort with Dun and Bradstreet employer searches. Work-related amputation medical records collected through the MMSIISS

were abstracted and entered into an Access database. An Excel file of the data reported by employers to OSHA was obtained from OSHA and uploaded into an Access database. The χ^2 test for trend was used to examine employer reporting compliance by year. The Two-sample *T* test was used to compare average ages in reports by employers to OSHA with the hospital reports to the MMSIISS. Logistic regression was employed to calculate odds ratios and then back-transformed to calculate the percent of employers and the 95% confidence intervals of the percentages of employers in compliance with the OSHA reporting rule by gender, amputation type, industry, source of amputation, and employer size for the 1366 workers reported either through employers to OSHA or by hospitals to the MMSIISS.[10] For the 126 of 1153 work-related amputation cases who were hospitalized overnight who were reported to the MMSIISS, the Mann–Whitney *U* test was used to compare the distribution of LOS between the employer reports to OSHA and those just reported to the MMSIISS but not reported by employers to OSHA. χ^2 Tests were used to test the differences in citations during inspections where cases were reported by employers to OSHA and inspections based on cases only reported by hospitals to the MMSIISS. All statistical analyses were carried out using SAS version 9.4 and used the statistical significance level of α set at 0.05.

We conducted a capture–recapture analysis to estimate the total number of work-related amputations.[11] We used a log-linear model to estimate the population size, where we assumed the catchability of the patients in the population followed the beta distribution.[12] R package "Rcapture" was used to estimate the population size.[13]

On-site OSHA enforcement inspections were conducted at some of the employers where workers sustained an amputation. We have previously described the various reasons on how an OSHA inspection can be initiated.[3] Enforcement inspections were performed at employers where amputations occurred that were reported either by the employer to OSHA or through hospital reporting to the MMSIISS. Inspections based on employer reports to OSHA were conducted closer to the time of injury, typically within 1 month, since the law requires employer reporting within 24 h of the amputation. Inspections based on hospital reports to the MMSIISS were conducted within 6 months of the hospital visit, given that hospitals submitted their reports on a quarterly basis. Federal OSHA uses three categories for determining whether an inspection will be conducted. Category 1 requires an inspection due to the severe nature of the injury; Category 2 indicates a less serious injury that may result in an on-site inspection; and Category 3 indicates a less severe injury that would only require correspondence with the employer to assure the hazard was corrected.[14] In Michigan, enforcement inspections were conducted where the amputation was severe and appeared to be caused by a correctable hazard covered by OSHA regulations. We searched the online portal for the OSHA Information System (OIS) to obtain information for each establishment that was inspected. The OIS search results included establishment name, union status, type of industry (NAICS code), specific rules violated, the classification of the citations, total fines assessed and, in many cases, a narrative of the events surrounding the amputation. We abstracted this information into an Access database.

This public health activity was considered exempt by the Michigan State University Human Subjects Board.

3 | RESULTS

There were 1366 work-related amputations from 2016 to 2018 in Michigan; 575 amputations were reported by employers to OSHA and 1153 amputations were reported by hospitals to the MMSIISS. There was an overlap of 362 cases reported by both employers and the hospitals, while 213 cases were only reported by employers to OSHA and 791 cases were only reported by hospitals to the MMSIISS. Figure 1 shows the overlap of the 1366 work-related amputations reported by employers and hospitals. Overall, 575 of 1366 (42.1%) of work-related amputations were reported by employers to OSHA; in 2016 177 of 447 (39.6%), in 2017 197 of 439 (44.9%), and in 2018 201 of 480 (41.9%). Compliance with employer reporting of amputations to OSHA did not significantly improve over the 3 years, p value = 0.30.

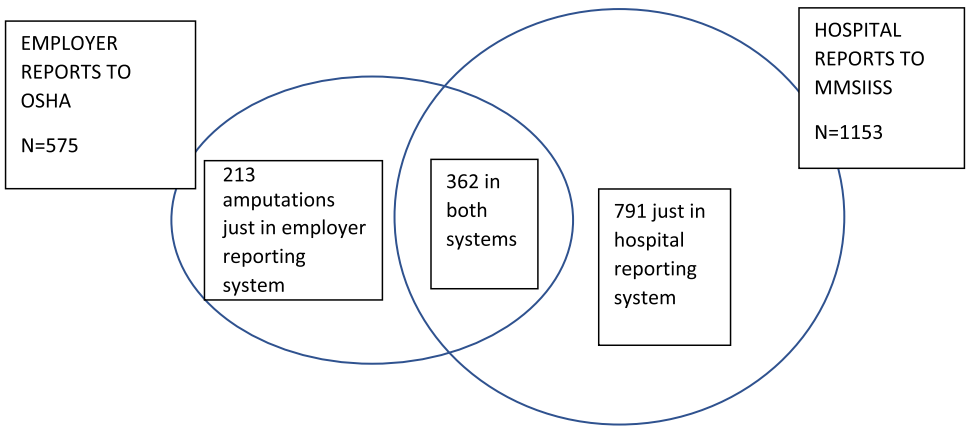

FIGURE 1 Overlap of two reporting systems for 1366 work-related amputations: Employer reports to OSHA and hospital reports to the Michigan Multi-Source Injury and Illness Surveillance System (MMSIISS), Michigan 2016–2018.

Capture-recapture analysis estimated that there were another 465 (95% CI 370–561) work-related amputations not identified either by the hospitals or employer reports to OSHA. Just over half (724, 53.0%) of the 1366 work-related amputations were included in the Michigan workers' compensation paid claims database.

Table 1 presents gender and average age by reporting source. Race and Hispanic Ethnicity were not available in the data set of employer reports to OSHA only ($n = 213$), therefore Table 1 presents the distribution of race and Hispanic Ethnicity across the 791 reports to the MMSIISS only and the 362 reports in both the MMSIISS and employer reports to OSHA. Where information is available for work-related amputations regardless of the system in which they were reported, the results compare employer compliance of reporting to OSHA with the total number of 1366 work-related amputations from 2016 to 2018 for amputation type (Table 2), industry type (Table 3), source of injury (Table 4), employer size (Table 5), and source of injury within manufacturing and construction (Supporting Information: Tables I and II).

Most of the amputations reported were among males (88.3%). There was no statistical difference in employer reporting compliance to OSHA by gender (males 41.8% [95% CI, 39.0, 44.6] compared with females 42.8% [95% CI 35.1, 50.5]). The workers who had an amputation ranged from 15 to 80 years of age. There was no statistically significant difference on average age by employer reporting compliance to OSHA, p value 0.430 (Table 1). Race was unknown for 741 (54.2%) of the 1366 workers. Hispanic ethnicity was unknown for 1054 (77.2%) of the 1366 workers. For reports where race and Hispanic ethnicity were known, the percentage of Black workers was not significantly different (13.2% vs 8.6%, p value = 0.25) and the percentage of workers of Hispanic and non-Hispanic ethnicity was not significantly different (13.0% vs. 18.9%, p value = 0.20) among workers reported by employers to OSHA compared with reports of workers in the MMSIISS (Table 1).

Most of the work-related amputations were of the upper extremity (elbow/forearm, shoulder/upper arm, wrist/hand/finger) and accounted for 1306 (96.0%) of the amputations. Of the 1296 wrist/hand/finger amputations, 1073 were of a single digit, with 776 at the distal interphalangeal joint (DIP), 109 at the proximal interphalangeal joint (PIP), 51 at the metacarpophalangeal joint (MCP), 2 at the arm, and 135 single digit amputations had an unknown degree of severity. Of the 203 amputations involving multiple digits, 88 were at the DIP, 26 at the PIP, 27 at the MCP, 8 at the wrist, 1 at the arm, and 53 multiple digit amputations had an unknown degree of severity. For another 20 individuals, the number of digits and degree of severity were unknown. Lower extremity amputations accounted for 54 (4.0%) of the amputations. Most of the lower extremity amputations were of the ankle/foot/toe (44), followed by lower leg (8), and two were hip/thigh (Table 2). Of the 44 foot/toe amputations, 23 were a single foot amputation, 11 were a single toe amputation, 4 had multiple toes amputated, 3 involved a trans metatarsal joint amputation of a single toe, and 3 were not specified. The 575 (362 plus 213) workers reported by their employer in compliance with the OSHA regulation had a similar distribution of type of amputation (Table 2). Employer compliance ranged from

TABLE 1 Demographics of 1366 work-related amputations by reporting source, 2016–2018.

	Reporting source			
	MMSIISS only ($n = 791$)	MMSIISS and employer reports to OSHA ($n = 362$)	Employer reports to OSHA only ($n = 213$)	All ($n = 1366$)
Gender	# (%)	# (%)	# (%)	# (%)
Male	700 (88.5)	328 (90.6)	175 (83.7)	1203 (88.3)
Female	91 (11.5)	34 (9.4)	34 (16.3)	159 (11.7)
Unknown gender	0	0	4	4
Average age, SD	39.0 ± 14.2	39.7 ± 13.0	41.0 ± 13.3	39.3 ± 13.8
Unknown age	1	0	142	143
Race				
White	363 (86.4)	169 (82.4)		532 (85.1)
Black	36 (8.6)	27 (13.2)		63 (10.1)
Asian	2 (0.5)	2 (1.0)		4 (0.6)
Other	19 (4.5)	7 (3.4)		26 (4.2)
Unknown race	371	157	213	741
Hispanic ethnicity				
Yes	40 (18.9)	13 (13.0)		53 (17.0)
No	172 (81.1)	87 (87.0)		259 (83.0)
Unknown ethnicity	579	262	213	1054

TABLE 2 Body part of 1366 work-related amputations by reporting source, Michigan 2016–2018.

	Reporting source				
	MMSIISS only (n = 791)	MMSIISS and employer reports to OSHA (n = 362)	Employer reports to OSHA only (n = 213)	All (n = 1366)	% Employers in compliance with reporting rule
Body part	# (%)	# (%)	# (%)	# (%)	% [95 C.I.]
Shoulder/upper arm	1 (0.1)	1 (0.3)	0	2 (0.1)	50 [0,1]
Elbow/forearm	6 (0.8)	2 (0.6)	0	8 (0.6)	25 [0,55]
Wrist/hand/finger	753 (95.6)	340 (93.9)	203 (96.7)	1296 (95.3)	41.9 [39.2,44.6]
Hip/thigh	2 (0.3)	0	0	2 (0.1)	0
Lower leg	3 (0.4)	2 (0.6)	3 (1.4)	8 (0.6)	62.5 [29,96]
Ankle/foot/toe	23 (2.9)	17 (4.7)	4 (1.9)	44 (3.2)	47.7 [33,62.5]
Totals and overall compliance	788	362	210	1360	42.1 [39.5,44.7]
Other/unknown	3		3	6	

25.0% for elbow/forearm amputations, to 62.5% for lower leg amputations; there were no statistically significant differences in employer compliance rates compared with the overall compliance rate (42.1%) by body part. Based on the narratives in our data set, we identified four individuals with a partial amputation who required surgical amputation; we do not have information on failed reattachments since we only have the medical records from the first encounter.

There were 126 of 1153 work-related amputations in the MMSIISS with an inpatient overnight hospital stay; the rest were outpatient (98, 8.5%), emergency department visits (917, 79.5%), or other outpatient visit such as observation (12, 1.0%). One hundred and thirteen of the 126 inpatient work-related amputations had a known LOS; the median was 2 days, ranging from a low of 1 day to a high of 24 days. The total number of days hospitalized for the 113 workers in the MMSIISS was 397 days. Within the subset of 362 workers in the MMSIISS that were also reported by employers to OSHA, 57 of the 65 workers had a known LOS; the median was 3 days, and the range of days was 24, including one worker who sustained a leg amputation. The total number of days hospitalized for the 57 workers with known LOS reported by employers to OSHA was 233 days. The range of days for 56 of 61 workers with known LOS only reported to the MMSIISS was 1–13. The total number of days hospitalized for the 56 workers with known LOS only reported to the MMSIISS was 164 days. There was no significant difference in the median of LOS between the employer reports to OSHA and those only reported to the MMSIISS, p value = 0.246.

Only employers in manufacturing (59.8%) were significantly more likely to report amputations to OSHA compared with the overall compliance rate where industry was known (44.2%). Employers in agriculture, forestry, fishing, and hunting (14.6%); construction (27.4%); retail trade (20.7%); arts, entertainment, and recreation (7.7%); accommodation and food services (13.0%) and all other services except public administration (27.0%) were significantly less likely to report amputations to OSHA compared with the overall compliance rate (Table 3). The percentage of employers in compliance with the reporting requirement varied from a low of 7.7% in arts, entertainment, and recreation to a high of 66.7% in utilities. The comparison for Table 3 is compliance within each industry category where amputations were reported. We did not calculate rates for amputations by industry type. We have published amputation rates by industry in previous publications[15] and annual reports.[16] In 2017, in Michigan, the agriculture, forestry, fishing and hunting industry had the highest rate of amputations (55.0/100,000 workers), followed by manufacturing (28.3/100,000 workers), construction (23.3/100,000 workers) and then all other industries (0.0–6.7/100,000 workers).[16]

Being pinched between two items (244, 18.8%), saws (179, 13.8%), being caught in a running machine (132, 10.1%), and presses (128, 9.8%) accounted for over half of the sources for the amputations (Table 4). Amputations resulting from being caught in a running machine (58.3%), involving a forklift (66.7%) and being caught in a chain or hoist (68.6%) were significantly more likely to be the hazard source among amputations reported by employers to OSHA compared with the overall compliance rate (43.8%) where injury source was known. Other machine-related contact (30.9%), knives (21.0%), and food slicers, mixers, or grinders (25.0%) were significantly less likely to be reported by employers compared with the overall compliance rate.

For manufacturing and construction, there were sufficient numbers of cases to examine employer compliance rates by source of injury within these two industries. Supporting Information: Tables I and II show employer compliance for manufacturing and construction by injury source. Within manufacturing, being caught in a running machine (76.4%) was significantly more likely to be reported by the employer compared with the overall compliance rate of 61.2% in manufacturing while any other machine-related contact (37.0%) was significantly less likely to be reported by the employer to OSHA compared with the overall compliance rate. Within the construction industry, there were no significant differences in source of amputation and compliance with the reporting requirement compared with

TABLE 3 Industry of 1366 work-related amputations by reporting source, Michigan 2016–2018.

	Reporting source				
	MMSIISS only (*n* = 791)	MMSIISS and employer reports to OSHA (*n* = 362)	Employer reports to OSHA only (*n* = 213)	All (*n* = 1366)	% Employers in compliance with reporting rule
Industry (NAICS)	# (%)	# (%)	# (%)	# (%)	% [95 C.I.]
Agriculture, forestry, fishing and hunting (11)	41 (5.7)	5 (1.4)	2 (0.9)	48 (3.7)	14.6 [4.6,24.6] ▼
Mining, quarrying, and oil and gas exploration (21)	5 (0.7)	0	1 (0.5)	6 (0.5)	16.7 [−13.2,46.5]
Utilities (22)	1 (0.1)	2 (0.6)	0	3 (0.2)	66.7 [13.3,120]
Construction (23)	90 (12.4)	25 (6.9)	9 (4.2)	124 (9.6)	27.4 [19.6,35.3] ▼
Manufacturing (31,32,33)	261 (36.0)	245 (67.9)	143 (67.1)	649 (50.0)	59.8 [56,63.6] ▲
Wholesale trade (42)	39 (5.4)	18 (5.0)	14 (6.6)	71 (5.5)	45.1 [33.5,56.6]
Retail trade (44,45)	65 (9.0)	11 (3.0)	6 (2.8)	82 (6.3)	20.7 [12,29.5] ▼
Transportation and warehousing (48,49)	28 (3.9)	8 (2.2)	4 (1.9)	40 (3.1)	30 [15.8,44.2]
Information (51)	0	0	0	0	
Finance and insurance (52)	1 (0.1)	0	1 (0.5)	2 (0.2)	50 [−19.3,119.3]
Real estate and rental and leasing (53)	5 (0.7)	1 (0.3)	0	6 (0.5)	16.7 [−13.2,46.5]
Professional, scientific, and technical services (54)	14 (1.9)	3 (0.8)	6 (2.8)	23 (1.8)	39.1 [19.2,59.1]
Management of companies and enterprises (55)	0	1 (0.3)	0	1 (0.1)	
Administrative and support and waste management and remediation services (56)	37 (5.1)	17 (4.7)	7 (3.3)	61 (4.7)	39.3 [27.1,51.6]
Educational services (61)	10 (1.4)	5 (1.4)	3 (1.4)	18 (1.4)	44.4 [21.5,67.4]
Health care and social assistance (62)	11 (1.5)	6 (1.7)	3 (1.4)	20 (1.5)	45 [23.2,66.8]
Arts, entertainment, and recreation (71)	12 (1.7)	1 (0.3)	0	13 (1.0)	7.7 [−6.8,22.2] ▼
Accommodation and food services (72)	67 (9.3)	4 (1.1)	6 (2.8)	77 (5.9)	13 [5.5,20.5] ▼
Other services (except public administration) (81)	27 (3.7)	5 (1.4)	5 (2.3)	37 (2.9)	27 [12.7,41.3] ▼
Public administration (92)	10 (1.4)	4 (1.1)	3 (1.4)	17 (1.3)	41.2 [17.8,64.6]
Totals and overall compliance	724	361	213	1298	44.2 [41.7,46.7]
Unknown	67	1	0	68	

Note: "▲" indicates significantly higher compliance rate than overall compliance rate and "▼" indicates significantly lower compliance rate than overall compliance rate.

the overall compliance rate of 29.0% in the construction industry. Small numbers within the other industry groupings did not allow for stratification and analysis of amputation source.

Large employers were significantly more likely to report the amputation to OSHA (67.9%) compared with the overall compliance rate of 45.7%, while small employers were significantly less likely to report the amputation to OSHA (18.2%) compared with the overall compliance rate (Table 5). Where employer size was known, 29 of 225 (12.9%) small companies, 204 of 707 (28.9%) medium size companies, and 94 of 321 (29.3%) large companies reported were inspected.

Three hundred and twenty-seven of 1366 (23.9%) of the employers were inspected by MIOSHA where a work-related amputation occurred; for 76 inspections the amputation was only

TABLE 4 Source of injury of 1366 work-related amputations by reporting source, Michigan 2016–2018.

	Reporting source				
	MMSIISS only (*n* = 791)	MMSIISS and employer reports to OSHA (*n* = 362)	Employer reports to OSHA only (*n* = 213)	All (*n* = 1366)	% Employers in compliance with reporting rule
Source	# (%)	# (%)	# (%)	# (%)	% [95 C.I.]
Pinched between two items	134 (18.3)	68 (18.8)	42 (20.2)	244 (18.8)	45.1 [38.8,51.3]
Saw	107 (14.6)	44 (12.2)	28 (13.5)	179 (13.8)	40.2 [33,47.4]
Caught in a machine that was running	55 (7.5)	48 (13.3)	29 (13.9)	132 (10.1)	58.3 [49.9,66.7] ▲
Press	62 (8.5)	51 (14.1)	15 (7.2)	128 (9.8)	51.6 [42.9,60.2]
Other machine-related contact	76 (10.4)	25 (6.9)	9 (4.3)	110 (8.5)	30.9 [22.3,39.5] ▼
Struck by an object	61 (8.3)	26 (7.2)	17 (8.2)	104 (8.0)	41.3 [31.9,50.8]
Caught in a pulley, belt, or conveyor	40 (5.5)	22 (6.1)	18 (8.7)	80 (6.1)	50 [39,61]
Knife	49 (6.7)	4 (1.1)	9 (4.3)	62 (4.8)	21 [10.8,31.1] ▼
Other contact with objects	32 (4.4)	17 (4.7)	4 (1.9)	53 (4.1)	39.6 [26.5,52.8]
Food slicer, mixer or grinder	36 (4.9)	6 (1.7)	6 (2.9)	48 (3.7)	25 [12.8,37.2] ▼
Forklift	12 (1.6)	12 (3.3)	12 (5.8)	36 (2.8)	66.7 [51.3,82.1] ▲
Caught in a chain or hoist	11 (1.5)	16 (4.4)	8 (3.8)	35 (2.7)	68.6 [53.2,84] ▲
Other sharp object	24 (3.3)	10 (2.8)	1 (0.5)	35 (2.7)	31.4 [16,46.8]
Caught in machine gears or sprocket	8 (1.1)	10 (2.8)	4 (1.9)	22 (1.7)	63.6 [43.5,83.7]
Landscaping and maintenance activity	16 (2.2)	3 (0.8)	2 (1.0)	21 (1.6)	23.8 [5.6,42]
Bit by an animal or human	8 (1.1)	0 (--)	4 (1.9)	12 (0.9)	33.3 [6.7,60]
Totals and overall compliance	731	362	208	1301	43.8 [41.2,46.4]
Other/unknown	60	0	5	65	

Note: "▲" indicates significantly higher compliance rate than overall compliance rate and "▼" indicates significantly lower compliance rate than overall compliance rate.

reported by a hospital to the MMSIISS, for 175 inspections the amputation was reported both by a hospital to the MMSIISS and by the employer to OSHA, and for 76 inspections the amputation was only reported by the employer to OSHA (Table 6). Figure 2 shows the overlap of inspections across the two reporting systems. Two hundred and thirty (70.3%) of the employers inspected had fewer than 250 employees, with 31 (9.5%) having 1–10 employees, and 199 (60.9%) having 11–249 employees.

Manufacturing (259, 79.2%) and wholesale trade (15, 4.6%) had the greatest number of inspections, followed by construction and retail trade (8, 2.4% each), agriculture, forestry, fishing and hunting (7, 2.1%), administrative and support and waste management and remediation services (6, 1.8%), professional, scientific, and technical services (5, 1.5%), health care and social assistance and other services except public administration (4, 1.2% each), transportation and warehousing and accommodation and food services (3, 0.9% each), educational services (2, 0.6%), and utilities, arts, entertainment and recreation and public administration (1, 0.3% each). There were no inspections in mining, quarrying, and oil and gas extraction, information services, finance and insurance, real estate and rental and leasing, and management of companies and enterprises.

We only know if a company was unionized if the facility was inspected. Of the 327 companies inspected, 55 (16.8%) were unionized; 48 of 259 (18.5%) manufacturing facilities were unionized, and in construction, 2 of 8 (25.0%) companies inspected were unionized. One of 15 companies inspected in wholesale trade was unionized, both companies inspected in educational services were unionized, and each single company inspected in the utilities and public administration industries were unionized. There was no union representing the workers at 272 (83.2%) of the employers inspected. Employer reporting to OSHA occurred in 51 (92.7%) of the 55 known unionized employers inspected and for 200 (73.5%) of 272

TABLE 5 Employer size of 1366 work-related amputations by reporting source, Michigan 2016–2018.

	Reporting source				
	MMSIISS only (*n* = 791)	MMSIISS and employer reports to OSHA (*n* = 362)	Employer reports to OSHA only (*n* = 213)	All (*n* = 1366)	% Employers in compliance with reporting rule
Employer size	# (%)	# (%)	# (%)	# (%)	% [95 C.I.]
Large (250+ employees)	103 (15.1)	131 (36.4)	87 (40.8)	321 (25.6)	67.9 [62.8,73] ▲
Medium (11–249 employees)	393 (57.8)	195 (54.2)	119 (55.9)	707 (56.4)	44.4 [40.8,48.1]
Small (1–10 employees)	184 (27.1)	34 (9.4)	7 (3.3)	225 (18.0)	18.2 [13.2,23.3] ▼
Totals and overall compliance	680	360	213	1253	45.7 [43.1,48.3]
Unknown	111	2	0	113	

Note: "▲" indicates significantly higher compliance rate than overall compliance rate. "▼" indicates significantly lower compliance rate than overall compliance rate.

known non-unionized employers inspected; unionized employers had significantly higher reporting to OSHA compared with non-unionized employers, *p*-value = 0.002.

Fifty-four (16.5%) of the 327 inspected employers were cited for failure to report the amputation. Forty-five of the 76 (59.2%) inspections where the amputation was only reported through the MMSIISS, and 9 of the 251 (3.6%) inspections where the employer did report the amputation to OSHA were cited for failure to comply with the reporting regulation. The nine employers who did report the amputation to OSHA yet were still cited for violation of the reporting regulation, had all reported the amputation greater than 24 h after the injury, but before the inspection occurred. Employers were cited for 403 violations, 289 (71.7%) of which were serious violations. A total of $947,060 in penalty fines were issued, with an average of $2896. Of the 327 inspections, 179 (54.7%) employers had not abated the hazard directly associated with the amputation in the time between the injury and the inspection, 62 (19.0%) had abated the hazard directly associated with the amputation before the inspection, 8 (2.4%) employers were only cited for not reporting the amputation, 2 (0.6%) were only cited for violations not directly related to the amputation, and 76 (23.2%) employers were not issued any citations (Table 7). If an employer had not reported the amputation to OSHA (MMSIISS only), they were not significantly more likely to be cited for a hazard, 62 of 76 (81.6%) compared with 179 of 251 (71.3%) that did report to OSHA, *p* value = 0.07, but they were significantly more likely to not have abated the hazard at the time of inspection, 53 of 76 (69.7%) compared with 126 of 251 (50.2%), *p* value < 0.01.

The median duration from date of injury to date of inspection for the 76 inspected employers only reported by hospitals to the MMSIISS was significantly longer, with 125 days while the median duration for the 251 inspections where the employer had reported the amputation to OSHA was 25 days, *p* value < 0.01. There were no significant differences in median duration by violation status, *p* value = 0.197. The median duration from time of injury to time of inspection where the employer was cited for a hazard directly related to the amputation and not abated at the time of inspection was 31 days; for inspections where the employer was cited for a hazard directly related to the amputation and had abated the hazard before the inspection was 38 days; for inspections cited for not reporting or cited for an unrelated hazard was 135 days, and for inspections not cited for anything was 24.5 days.

3.1 | Two narratives of work-related amputations where OSHA conducted an enforcement inspection

A press operator at an iron plate manufacturer was loading a part into a press brake to bend the part. A coworker actuated the press and the employee's finger was amputated. The employer was inspected 62 days after the incident. The hazard was still present at the time of inspection. This amputation was only reported to the MMSIISS and not by the employer to OSHA. The employer was cited for six serious violations. The first three violations were for failure to equip the press with an actuation device for each employee who is exposed to a point of operation hazard, requiring concurrent use of all actuation devices, failure to provide a machine guard, and failure to provide training for each newly assigned employee. The next three violations related to lockout and included failure to provide training on the recognition of applicable hazardous energy sources, the type and magnitude of the energy in the workplace and how to isolate and control the energy source, and for failure to periodically inspect energy control procedures at least annually. The employer was fined $2300.

A saw operator at a home improvement center was unloading wood off a conveyor. The employee's left hand became caught between the chain and sprocket of the conveyor, and their left index and middle fingers were amputated. The employer was inspected 170 days after the incident. The unguarded chain and sprocket were still present at the time of inspection. This amputation was only reported to the MMSIISS and not by the employer to OSHA. The employer was cited for one serious violation for failure to enclose the workstation of the operator of a circular saw, and one repeat violation for failure to guard gears, sprockets, and chain drives exposed to contact. They were also cited for failure to report the amputation. They were fined $2400.

TABLE 6 Inspections, violations, and monetary penalty of 327 enforcement inspections of work-related amputations by reporting source and industry, and distribution by industry of employers in the MMSIISS or employer reports to OSHA that were not inspected, Michigan 2016–2018.

	Reporting source						Employers in MMSIISS or employer reports to OSHA that were not inspected ($n = 1039$)[a]		
	MMSIISS only Inspections ($n = 76$)	MMSIISS and employer reports to OSHA Inspections ($n = 175$)	Employer reports to OSHA only Inspections ($n = 76$)	All inspections Inspections ($n = 327$)	Total violations	Total penalty $	Did employer report to OSHA? Yes ($n = 324$)	No ($n = 715$)	All ($n = 1039$)
Industry (NAICS)	# (%)	# (%)	# (%)	# (%)	#	$	# (%)	# (%)	# (%)
Agriculture, forestry, fishing and hunting (11)	2 (2.6)	5 (2.9)	0	7 (2.1)	9	19,750	2 (0.6)	39 (6.0)	41 (4.2)
Mining, quarrying, and oil and gas extraction (21)	0	0	0	0	0	0	1 (0.3)	5 (0.8)	6 (0.6)
Utilities (22)	0	1 (0.6)	0	1 (0.3)	1	3500	1 (0.3)	1 (0.2)	2 (0.2)
Construction (23)	1 (1.3)	4 (2.3)	3 (3.9)	8 (2.4)	6	4800	27 (8.4)	89 (13.7)	116 (11.9)
Manufacturing (31,32,33)	57 (75.0)	140 (80.0)	62 (81.6)	259 (79.2)	312	789,400	186 (57.6)	204 (31.5)	390 (40.2)
Wholesale trade (42)	3 (3.9)	7 (4.0)	5 (6.6)	15 (4.6)	22	36,675	20 (6.2)	36 (5.6)	56 (5.8)
Retail trade (44,45)	4 (5.3)	3 (1.7)	1 (1.3)	8 (2.4)	12	16,585	13 (4.0)	61 (9.4)	74 (7.6)
Transportation and warehousing (48,49)	1 (1.3)	2 (1.1)	0	3 (0.9)	3	7000	10 (3.1)	27 (4.2)	37 (3.8)
Information (51)	0	0	0	0	0	0	0	0	0
Finance and insurance (52)	0	0	0	0	0	0	1 (0.3)	1 (0.2)	2 (0.2)
Real estate and rental and leasing (53)	0	0	0	0	0	0	1 (0.3)	5 (0.8)	6 (0.6)
Professional, scientific, and technical services (54)	2 (2.6)	2 (1.1)	1 (1.3)	5 (1.5)	9	12,550	6 (1.9)	12 (1.9)	18 (1.9)
Management of companies and enterprises (55)	0	0	0	0	0	0	1 (0.3)	0	1 (0.1)
Administrative and support and waste management and remediation services (56)	3 (3.9)	1 (0.6)	2 (2.6)	6 (1.8)	8	11,200	21 (6.5)	34 (5.2)	55 (5.7)
Educational services (61)	0	2 (1.1)	0	2 (0.6)	1	3150	6 (1.9)	10 (1.5)	16 (1.6)
Health care and social assistance (62)	2 (2.6)	1 (0.6)	1 (1.3)	4 (1.2)	7	19,050	7 (2.2)	9 (1.4)	16 (1.6)
Arts, entertainment, and recreation (71)	0	1 (0.6)	0	1 (0.3)	2	3500	0	12 (1.9)	12 (1.2)

(Continues)

TABLE 6 (Continued)

	Reporting source			All inspections			Employers in MMSIISS or employer reports to OSHA that were not inspected (n = 1039)[a]		
	MMSIISS only Inspections (n = 76)	MMSIISS and employer reports to OSHA Inspections (n = 175)	Employer reports to OSHA only Inspections (n = 76)	Inspections (n = 327)	Total violations	Total penalty $	Did employer report to OSHA? Yes (n = 324)	No (n = 715)	All (n = 1039)
Accommodation and food services (72)	0	2 (1.1)	1 (1.3)	3 (0.9)	2	7350	7 (2.2)	67 (10.3)	74 (7.6)
Other services (except public administration) (81)	1 (1.3)	3 (1.7)	0	4 (1.2)	7	7400	7 (2.2)	26 (4.0)	33 (3.4)
Public administration (92)	0	1 (0.6)	0	1 (0.3)	2	5150	6 (1.9)	10 (1.5)	16 (1.6)
Total	76	175	76	327	403	947,060	323	648	971

[a]There were 68 individuals in the MMSIISS for which NAICS was unknown: one who was reported by their employer to OSHA and 67 of whom were only reported by a hospital to the MMSIISS.

4 | DISCUSSION

Employer compliance with the OSHA requirement to report a work-related amputation within 24 h of its occurrence could be examined because of the MMSIISS, which is a unique surveillance tool based on the requirement in Michigan that hospitals report work-related injuries including amputations. We used the MMSIISS data to understand the characteristics of the workers who sustained amputations and to evaluate employer compliance with the reporting requirement of these work-related amputations. We found that for 42.1% of the amputations, employers complied with the reporting regulation from 2016 to 2018, and that despite extensive outreach to employers, compliance with the regulation did not significantly improve over the 3-year period. Employer compliance for reporting amputations did not significantly differ by body part; it was highest for reporting amputations of the lower leg (62.5%), although the number of lower leg amputations was small, with eight cases (Table 2). Compliance was significantly greater in the manufacturing industry (Table 3), among large employers with 250 or more employees (Table 5), and among unionized employers. Small employers with 10 or fewer employees were the least compliant with reporting, but also the least likely to be inspected (13% of small companies compared with 29% each of medium and large companies were inspected). We found that at the time of the opening date of the inspection, employers had not abated the hazards that caused the amputation in over half (54.7%) of the inspections (Table 7). Ongoing serious hazards were identified during the workplace enforcement inspections highlighting the public health importance of continued surveillance for work-related amputations linked to OSHA enforcement inspections.[17]

Federal OSHA conducted an impact evaluation of the reporting requirement for federal OSHA states, 1 year after its requirement went into effect, identifying 2644 work-related amputations reported by employers during calendar year 2015.[2] They performed on-site inspections for 58% of the amputation reports. They concluded that perhaps 50% or more injuries were not being reported by employers to OSHA based on a comparison with workers' compensation injury claim numbers available for some of the federal plan states. They also concluded that the new reporting requirement was successful in helping OSHA focus their resources where they were most warranted and in helping employers identify and eliminate serious hazards. OSHA was not able to compare work-related amputations to workers' compensation claims across all the federal OSHA states as the data was not readily available for all the states.[14] In Michigan, of the 1366 work-related amputations we identified, only 724 (53.0%) were paid a workers' compensation award, suggesting that caution must be used when using workers' compensation data to assess compliance with the reporting regulation.

In 2018, the US Department of Labor Office of Inspector General (OIG) of Audit issued a report, "OSHA Needs to Improve the Guidance for Its Fatality and Severe Injury Reporting to Better Protect Workers."[14] This report outlined the audit the OIG conducted to determine if OSHA had effectively implemented its

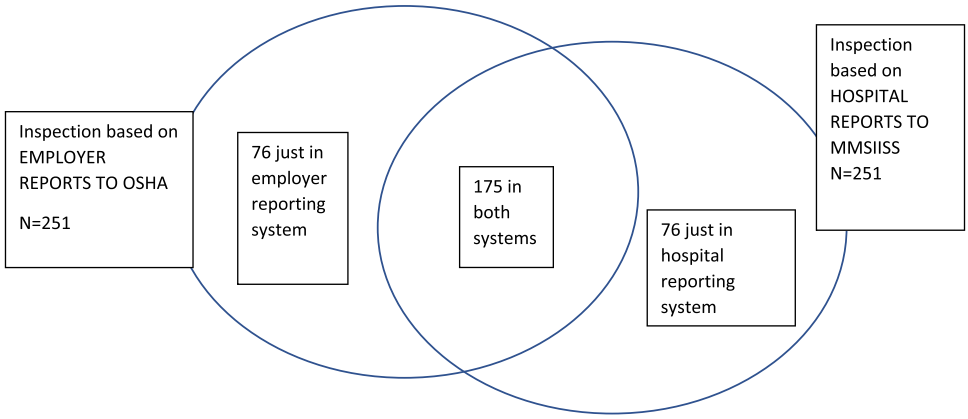

FIGURE 2 Overlap of 327 OSHA inspections based on workers in two reporting systems: Employer reports to OSHA and hospital reports to the Michigan Multi-Source Injury and Illness Surveillance System (MMSIISS), Michigan 2016–2018.

TABLE 7 Enforcement inspections for 327 work-related amputations by reporting source and violation status, Michigan 2016–2018.

	Reporting source			
	MMSIISS only	MMSIISS and employer reports to OSHA	Employer reports to OSHA only	Total
Violation status	# (%)	# (%)	# (%)	# (%)
Cited: Hazard directly related and not abated at time of inspection	53 (69.7)	92 (52.6)	34 (44.7)	179 (54.7)
Cited: Hazard directly related and was abated before inspection	9 (11.8)	34 (19.4)	19 (25.0)	62 (19.0)
Only cited for not reporting the injury[a]	5 (6.6)	3 (1.7)	0	8 (2.4)
Only cited for hazard(s) unrelated to the injury	1 (1.3)	1 (0.6)	0	2 (0.6)
Not cited for any violations	8 (10.5)	45 (25.7)	23 (30.3)	76 (23.2)
Total inspected	76	175	76	327
Not inspected	715	187	137	1039

[a]A total of 54 of the 327 employers inspected were cited for failure to report the injury; 8 of the 54 were only cited for failure to report and 46 were cited for other hazards in addition to failure to report.

severe injury reporting program. Based on their review, a number of recommendations were made surrounding training, issuing citations for late reporting, clarifying follow up to ensure employers were correcting hazards and conducting on-site inspections for the most severe injuries.

Fifty-four (16.5%) of the 327 employers inspected were cited for failure to report the amputation; 45 (59.2%) of the 76 employers inspected that were only reported by hospitals to the MMSIISS were cited for failure to report the amputation. Some of the reasons the employer was *not* cited for failure to report included that, although the medical record indicated an amputation, the employer representative reported that the injury was initially an avulsion, an open fracture, a crushing injury, or another type of injury or the actual amputation occurred more than 24 h after the work-related incident, which under the OSHA regulations did not need to be reported to OSHA within 24 h. Additional insight into why employers fail to comply with the reporting regulation could be gained if OSHA routinely collected the reason for not reporting the amputation during inspections at nonreporting companies. The reasons for noncompliance could then be used in educational and informational messages during health and safety conferences or during OSHA consultative visits to increase understanding and compliance with the reporting regulation.

Cross-referencing the MMSIISS with employer reports to OSHA proved useful in identifying nonreporters as well as gaps in both systems of case identification. Employers did not report 791 (57.9%) of the 1366 work-related amputations from 2016 to 2018. Conversely, although 100% of hospitals in Michigan complied with the 2010 Michigan regulation for reporting work-related injuries, matching the MMSIISS data with the employer reports to OSHA (Figure 1) showed that there were 213 reports of amputations from employers to OSHA that were not identified in the MMSIISS. For these 213 reports, it is possible that the amputation was less severe, not requiring treatment at a hospital, but rather at another type of

facility such as an urgent care clinic. However, if a worker first sought care at a lower-level medical facility, such as urgent care or private physician, if the amputation itself occurred within 24 h regardless of the point in time they ultimately sought care at a hospital, the case should have been identified and reported by the MMSIISS. To definitively understand these 213 reports by employers to OSHA that were not found in MMSIISS would necessitate that OSHA require employers who report amputations include the name of the hospital or other type of health care facility where the injured worker was treated so their medical records could be reviewed. Information on the medical facility where treatment occurred is also not available in the Michigan workers' compensation claims electronic file. Conversely, it would also be beneficial for hospitals to add a work-relatedness code in their electronic medical records systems to facilitate more complete case identification of all work-related conditions.[1] Additionally, our capture-recapture analysis estimated that there were another 465 (95% CI 370–561) work-related amputations not identified by either the hospitals or employers in Michigan for the 3 years. This estimate further emphasizes the limitations for case identification and importance of modifications in both reporting systems to identify cases and capture a more complete picture of this serious work-related injury.

While there has been no published evaluation of the new federal employer-reporting rule for amputations using hospital data specifically, there are prior studies which have identified undercounting in the employer-based BLS SOII.[6,7,18] Some of the barriers to employer reporting include lack of awareness of the requirement, lack of awareness of the injury or skepticism of its work-relatedness and cost-shifting practices to avoid increased workers' compensation costs.[9,18,19] A recent literature review of *employee* underreporting of injuries affirms the barriers include fear of reprisal from their employer, being unaware of reporting requirements, perception of the amount of effort needed to file a record of the injury, and perception that the injury is not severe.[9] Given the acute and dramatic nature of an amputation, we would consider that it would rarely be the case where an employer was unaware of the injury or questioned whether it was work-related. Underreporting by employers is more likely related to lack of awareness of the reporting regulation or deliberate disregard of the regulation.[2] Another possible explanation is that employers mistakenly believe they satisfied the reporting requirement by reporting through another outlet such as OSHA's Form 300, Summary of Work-Related Injuries and Illnesses.

Combining employer reports to OSHA with the MMSIISS allows a more complete picture of the nature, severity and circumstances surrounding work-related amputations. For example, a significantly higher percentage of employers in manufacturing (59.8%) complied with the reporting requirement and were overrepresented in the employer reports to OSHA system compared with hospital reports to the MMSIISS (67% vs. 36%) (Table 3). Michigan's National Emphasis Program (NEP) on Amputations in Manufacturing focuses on the manufacturing industry where the machinery and equipment have historically been associated with work-related amputations; this may in part explain the overrepresentation of manufacturing amputations reported by employers to OSHA. Although we only had information about union status for companies inspected by OSHA, compliance with reporting to OSHA was statistically higher in unionized facilities (92.7%) compared with non-unionized facilities (73.5%), p value = 0.002. Forty-eight (18.5%) of the 259 manufacturing companies inspected were unionized; this may in part explain better compliance with reporting in this industry sector. Employers had a significantly lower compliance rate in agriculture, forestry, fishing, and hunting (14.6%); construction (27.4%); retail trade (20.7%); arts, entertainment, and recreation (7.7%); accommodation and food services (13.0%); and other services except public administration (27.0%) which were all overrepresented in the hospital reports to the MMSIISS compared with the employer reports to OSHA (Table 3). Further, being caught in a running machine (58.3%), being injured by a forklift (66.7%), and being caught in a chain or hoist (68.6%) were all significantly more likely to be reported by the employer to OSHA, while other machine-related contact (30.9%), knife-related amputations (21.0%), and being caught in a food slicer, mixer or grinder (25.0%) were all significantly less likely to be reported by the employer to OSHA (Table 4). The knife and food processing amputations suggest more attention be made in the food services and food processing industries. In fact, federal OSHA identified a high number of food slicer amputations shortly after the reporting requirement went into effect and consequently developed a fact sheet on simple and low-cost ways to prevent these types of amputations; they conducted extensive outreach by mail, email, and an article in a food service industry publication.[2] The reporting requirement allows for the identification of industries and hazards where cost-effective safety measures can be implemented.

Work-related amputations represent a financial burden. A recent analysis of emergency department (ED) costs estimated the cost of an ED visit in 2016 was $943.2 (CI $934.3–$951.6).[20] Data from the Kaiser Family Foundation estimates that the average inpatient hospital stay per day in Michigan was $2245 for 2016, $2318 for 2017, and $2400 for 2018 (source: kff.org, accessed 1-20-2022). Most of the work-related amputations reported to the MMSIISS were ED visits (917, 79.5%), followed by inpatient stays (126, 10.9%), outpatient visits (98, 8.5%), and other such as observation (12, 1.0%). If we apply these estimated ED costs and average daily costs for each year to the number of ED visits and LOS for individuals with work-related amputations, the estimated ED and hospital costs for the 1153 workers in the MMSIISS would be $1,908,030; compared with $833,075 for the 362 workers reported by employers to OSHA, over a two-fold difference. The costs for the 213 work-related amputations only identified through employer reports to OSHA which do not have information on whether the workers were hospitalized, sought treatment in the ED or other medical facility, would further add to the overall financial burden. Further, there are the life-long hidden social and economic costs that cannot be quantified that are placed on workers who sustain these amputations.[5] The two narratives of workers with amputations give some examples of the type and seriousness of these injuries.

The employer reporting requirement is a useful tool to identify work-related amputations in a timely manner and direct enforcement

inspections at employers where the hazard still exists. Timely reporting to OSHA allows for more accurate inspections by OSHA, so hazards can be more fully understood and corrected while the information and site conditions regarding the amputation remain fresh.[14] Because of these inspections, there are direct benefits to co-workers, given that they are also potentially exposed to the same hazards. OSHA enforcement inspections require employers to remediate hazards and provide proof of such. Further, the fact that 54.7% of the employers inspected had not corrected the hazard directly related to the amputation at the time of inspection, usually 3 months after the amputation, demonstrates the usefulness of case identification and intervention in the workplace. An evaluation of the MMSIISS for amputations by the RAND Corporation found that "Inspections from the surveillance program found 2.60 times as many violations as other inspections and assessed approximately 2.45 times the amount of a typical inspection in monetary penalties… the Michigan program substantially influenced other state programs such as the one in Massachusetts. The program also provided better information on the extent of amputations in Michigan and in which industries and employers amputations had occurred that were not reported in other sources…our preliminary analysis suggests that NIOSH-supported surveillance programs likely have positive benefits."[21]

We have previously reviewed potential limitations for analyses using the two reporting systems for the injury not meeting the case definition criteria for the OSHA reporting requirement; however, given the availability of medical records, the ability to cross-reference with workers' compensation data and the ability to conduct follow-back with some of the workers who sustained an amputation where the employer name was unknown all would suggest a minimal effect on our findings.[3] Workers' compensation paid for 52.1% of the 1153 amputations in the MMSIISS allowing us to be confident that these amputations met the amputation case definition criteria for inclusion; for the other approximately half of the cases, we had sufficient information from the medical records to confirm they met the criteria for inclusion. The 213 amputations only reported by employers to OSHA, if they were hospitalized, might possibly have been coded with an ICD-10 code for a different injury type, such as lacerations or crushing injuries, especially if there were multiple injuries associated with the event. Again, if OSHA required employers to report the hospital or other medical facility where the worker sought care, we might better understand why these 213 amputations were missed. This would allow review of the medical records of these unreported amputations to determine why they were not reported (i.e., not treated at a hospital, medical record indicated injury other than an amputation, oversight by hospital).

Underrecording of work-related injuries has long been established.[8] Because of the MMSIISS, we were able to assess employer compliance with the reporting regulation for amputations. We have identified a gap of over 50% in reporting by employers to OSHA. As reported in the OIG audit, there is a continued need for awareness and enforcement of the reporting requirement at a national level given the serious nature of the ongoing hazards identified.[14] While the findings for Michigan may differ compared with other states in industries and the associated hazards, we would not expect the overall compliance with reporting findings to be any better in any other state, and potentially even worse in states that do not have longstanding special surveillance systems built on mandatory occupational disease and injury reporting laws such as Michigan's MMSIISS.

Poor compliance with the reporting regulation was across all 3 years, with no significant improvement in reporting from 2016 to 2018. Employer compliance was poor regardless of the degree of severity of the amputations, ranging from 25% for elbow/forearm amputations, to 62.5% for lower leg amputations. As we found when analyzing employer reporting of overnight hospitalizations (not including amputations), better compliance among manufacturing facilities and those with a large number of employees compared with other industries and smaller employers points to a need to increase awareness about the requirement as well as continue to offer OSHA consultative services to employers that lack the resources to identify workplace hazards and adequately provide a safe workplace. In Michigan, for employers who reported the amputation to OSHA, if they did not receive an on-site inspection, the employer usually received an inspection by letter from OSHA or was referred to OSHA's Consultation Education and Training (CET) Division for outreach services to address the hazard. Inspected employers not complying with the OSHA reporting regulation appeared to have a weaker health and safety program since not only did they not report but they were more likely to be cited for hazards and less likely to have abated the hazards causing the amputation months after the incident occurred (Table 7). The significantly longer median duration, 125 days, from date of injury to date of inspection of inspected employers only found in the MMSIISS possibly indicates that employers who do not report to OSHA are less likely to fix the hazard even though they have more time to do so before an inspection. Improvement in direct employer reporting of work-related amputations provides OSHA with more time to initiate an inspection given the 6-month time period limitation within which, for most cases, they initiate an inspection. The average time from injury to inspection of direct employer reports to OSHA was 25 days. This allows OSHA to better manage its workload since they have almost a full 6 months to respond, compared with hospital reported amputations which are reported quarterly and therefore have approximately 3 or fewer months to respond. Regardless of the source, improved compliance in reporting of work-related amputations will identify hazards posing a high risk for causing additional amputations to other workers from the same source of injury and help OSHA's enforcement and consultation programs target preventive and intervention safety efforts in industries that might otherwise be overlooked.

AUTHOR CONTRIBUTIONS

Mary Jo Reilly compiled the data and wrote the first draft of the manuscript. Kenneth D. Rosenman provided the concept idea for the manuscript, and contributed substantially to the writing and

edits. Ling Wang was responsible for the statistical analyses as well as edits to the manuscript. All three authors contributed substantially to the revised manuscript.

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The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

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Research data are not shared.

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Institution and Ethics approval and informed consent: This public health activity was considered exempt by the Michigan State University Human Subjects Board.

DISCLAIMER

The contents of the manuscript do not necessarily reflect the views of the funding agency.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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