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Variation in the Incidence of Distal Radius Fractures in the US Elderly as Related to Slippery Weather Conditions

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Abstract

Background—Distal radius fractures (DRFs) are costly and debilitating injuries, especially for the elderly. DRFs often occur from falls and more commonly occur outdoors. Inclement weather, especially in the winter, may increase the risk of fall-related injuries. Small community studies have reported increased risk of DRF due to inclement winter weather; however, larger studies are lacking.

Methods—We analyzed a sample of 2007 Medicare claims for DRF. Weather data were collected for the date and location of each DRF in our analysis cohort. A novel slipperiness score (0–7, 7 indicates the most slippery weather) was used as a measure of the severity of slippery outdoor conditions. Negative binomial regression models evaluated the correlation between slipperiness and DRF occurrence.

Results—Risk of DRF was higher in winter months (Incidence Rate Ratio=1.2, 95%CI 1.14–1.26, $p<0.001$). Days with average temperature $\geq 32^{\circ}\text{F}$ (IRR=1.36, 95%CI 1.19–1.54, $p<0.001$), snow/ice on ground at the start of the day (IRR=1.45, 95%CI 1.25–1.68, $p<0.001$), and freezing rain (IRR=1.24, 95%CI 1.03–1.49, $p=0.025$) all had an increased risk of DRF. Risk of sustaining a DRF was increased 21% on days with a slipperiness score of 5 or above (IRR=1.21, 95%CI 1.08–1.20, $p=0.007$). Additionally, for each increase in slipperiness score above 4, the IRR of DRF increased as well.

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Conclusions—Weather events that create slippery walking conditions, most often occurring in winter months, result in an increased risk of DRF in the US elderly. This finding can be used to support resource allocation as well as awareness and prevention campaigns.

Level of Evidence—IV; retrospective cohort

Introduction

Seasonal variation in trauma incidence, resulting in fluctuating volume of emergency department (ED) visits, orthopedic injuries, and surgical consultations and procedures, has been widely studied.^{1–5} Many reports identify the summer season as most busy for EDs due to a variety of factors, including increased outdoor activities and children being out of school.^{2, 3, 6} However, there is an additional subset of trauma volume that is attributed to periods of inclement weather that most often occur during the winter.^{7, 8} Many of these weather-related injuries occur as a result of slippery outdoor conditions.^{9–12} Extensive research has been conducted regarding road and vehicle safety, aimed at prevention of motor vehicle collisions during periods of dangerous weather.^{4, 13, 14} In the United States, as in other nations, winter road advisories are given.⁸ The Finnish Meteorological Institute (FMI) has also devised and validated a road weather model that provides citizens with timely road condition warnings during the winter.¹⁵ However, there is a paucity of data regarding sidewalk and walking safety during times of dangerous, slippery weather.

Nearly 90,000 Medicare beneficiaries sustain distal radius fractures (DRFs) each year, frequently resulting from a fall from standing height and more often occurring outdoors.^{16–18} These injuries incur expenditures topping \$240 million dollars annually.¹⁹ DRFs are functionally limiting, and in an elderly patient can result in loss of independence as well as higher risk of medical complications.^{20–23} Outdoor falls may be precipitated by slippery conditions, and an increased incidence of DRFs in winter months has been reported.^{24–27} Furthermore, winter weather events have been associated with an increased risk of fracture. In Rochester, Minnesota, the risk of DRF in women 65 years or older was significantly greater on days with snow or blowing snow (Relative Risk: 1.43) and on days with freezing rain or glaze (Relative Risk: 1.97).²⁴ Similar results were demonstrated in Oulu, Finland, where the risk for DRF was 2.5 times greater on days with winter weather.²⁷

These reports from smaller communities identify a relationship between slippery winter weather and DRF occurrence, a potential public health and safety issue. This project expands the scope to evaluate an association between inclement weather conditions and incidence of DRFs in the US Medicare population. We hypothesize that seasonal variation in the incidence of DRFs exists, and is associated with various winter weather events. Additionally, a slipperiness score (combining weather events) will be used, and will aid in identifying an increased risk of DRFs on days with more slippery conditions.

Materials and Methods

Medicare Data and Patient Cohort

This is a retrospective cohort study with an ecological perspective. From the US Centers for Medicare and Medicaid Services, we obtained complete (100%) data from 2007 for all claims including an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code for fracture of the radius and/or ulna (codes 813.00–813.93). Claims were taken from the Medicare Provider Analysis and Reviews (MedPAR) file (Part A claims) and the Outpatient and Carrier files (Part B claims). Beneficiaries were excluded from the analysis cohort if they had a claim indicating a diagnosis of bone or metastatic cancer, if they were enrolled in Medicare Part C, or were not enrolled in Parts A and B for all of 2007. We also excluded beneficiaries who were under 65 or over 99 years of

age on January 1, 2007. Americans who qualify for Medicare under age 65 are very different than those qualifying based on age. Beneficiaries over age 99 were removed to avoid miscoded birthdates.

As with any study utilizing Medicare data, we had to rely on the accuracy of the data provided. Medicare claims are created for billing purposes, rather than for research. Health systems and providers are careful to code procedures and diagnoses appropriately to ensure prompt and correct payment. Studies of the accuracy of Medicare claims support this, finding positive predictive values ranging from 86% to 99%.^{28–31}

To ensure that we were only capturing beneficiaries who truly had a DRF, we further limited our dataset to claims listing one of the ICD-9-CM codes most likely to represent a diagnosis of closed distal radius fracture (Table 1). The beneficiary's claim was also required to list one of fourteen Current Procedural Terminology (CPT) codes indicating treatment of a distal radial fracture (Table 1). Finally, to exclude prevalent fractures, we only included beneficiaries if they received treatment within two weeks of diagnosis.

For each beneficiary, the first claim in 2007 reporting a diagnosis of DRF was isolated. The date of this claim was used as the date of injury. The zip code of the hospital or clinic that first reported the diagnosis was considered the location of injury. Although treatment may have been provided elsewhere, the site first coding the diagnosis is most likely to be the emergency care center closest to the location of injury. DRFs that were diagnosed concurrently with additional trauma, including any other fracture, neurologic injury, solid organ injury (spleen laceration/contusion, bowel injury, diaphragmatic rupture, or kidney laceration), pneumothorax, and hemothorax, were considered “major” DRFs. Isolated DRFs that occurred without other major injuries were considered “minor” fractures and were perhaps more likely to have resulted from a fall.

Weather Data

Because airports keep detailed reports of local weather, we used selected airports as our sampling frame. To evaluate the various regions of the United States, while still achieving a large sample with adequate demographic diversity, the two largest airports serving the two largest cities in each of the 50 states and the District of Columbia were selected. In the event that one airport served the two largest cities, the next largest city was selected until a unique airport was identified. Owing to region size and airport saturation on the eastern seaboard, Washington, DC and Rhode Island each were assigned one airport for the analysis. A total of 100 airports were selected (Figure 1, Appendix 1).

Several sources were used to collect 2007 daily weather data for each airport. Data for 88 of the designated airports were obtained from Local Climatological Data (LCD) reports published by the National Climatic Data Center (NCDC) and the National Oceanic and Atmospheric Administration (NOAA).³² For the remaining 12 cities, open source weather data was not directly provided by these agencies. However, we were able to use alternate databases Weather Underground, Inc. and AccuWeather, Inc. that accessed and reported NOAA/NCDC data for these cities.^{33, 34}

For each airport, we obtained maximum temperature (°F), minimum temperature (°F), average daily temperature (°F), depth of snow and or ice on ground (inches) at noon Coordinated Universal Time, water equivalent of precipitation on ground (inches) at midnight local time, snowfall precipitation on ground (inches), maximum 5-minute wind speed (miles per hour) at 10 meters above the ground, and visibility (miles) for each day in 2007. We also coded weather events, including snow, rain, freezing rain, and others reported by NOAA.³²

The county or counties in which each of the 100 airports is located was recorded. Assuming that weather is relatively consistent across a county³⁵, all zip codes within each county were compiled and matched to zip codes of beneficiary location of injury. The resulting list of fractures per day per county was merged with airport weather per day. Using the minor and major fracture definitions described above, we divided counts into major and minor fractures per day for each airport county.

Statistical Analysis

Descriptive statistics were used to report cohort demographic data. Age distribution between the analysis cohort and the entire Medicare DRF population was evaluated using the Kolmogorov-Smirnov test. Other demographic and fracture-type comparisons were done using Pearson's Chi-square test. Monthly DRF incidence (fractures/day across each month) was evaluated with ANOVA, and Tukey's correction was used for pairwise comparisons. For all days when any of the weather variables occurred, the variance of fracture counts was greater than the mean. Considering this overdispersion, negative binomial regression (NBR) models were used to evaluate the association between winter weather events and DRFs. Adjustment was made for clustering at the county level to minimize county-specific effects. The magnitude of each fracture count is dependent on the at-risk population; therefore, the total population of residents 65 years and older in each county, based on 2007 intercensal estimates, was used as the exposure in the model. Incidence rate ratios (IRRs) indicate the increase in risk of sustaining DRF under the conditions evaluated in the model (e.g., an IRR of 1.15 indicates a 15% increase in risk).

Simple models were run to evaluate isolated weather events. However, due to concerns of potential multicollinearity (e.g., it is often below 32°F when there is snow), rather than add each weather event separately into one model we condensed key weather data into a slipperiness score. We weighted weather elements known to result in freezing of surface water and slippery conditions¹⁵ to calculate an overall score that measures the severity of slipperiness; the resulting scores can range from 0 to 7 (Table 2). Separate NBR models were then used to correlate this slipperiness score with total DRF occurrence, isolated (minor) DRF occurrence, and major DRF occurrence.

Although the slipperiness score is composed of weather events known to result in slippery conditions,¹⁵ without geothermal ground data we are unable to validate that this system represents actual slipperiness of sidewalks or roads. However, we used road safety data to support the accuracy of this score in indicating slippery conditions. Considering that the elements in our slipperiness score affect roads as well as sidewalks,³⁶ and knowing that automobile accidents occur more frequently in slippery weather,^{13, 14} data from the University of Michigan Transportation Research Institute was used in a NBR model to correlate slipperiness score with automobile accidents for all of 2007 in Ann Arbor, MI and across all of Wayne County, MI (Appendix 2). All statistical modeling was done using Stata 12.0 (StataCorp, College Station, TX).

Results

Using the selected counties as the sampling frame, 21,507 beneficiaries were included in the analysis cohort, representing 25% of Medicare beneficiaries sustaining DRFs in 2007 (Table 3). As is typical of elderly patients with DRFs, the DRF cohort and analysis cohort are significantly more female and white than the general US population. Age distribution ($p=0.65$) and gender distribution ($p=0.82$) were not significantly different between the analysis cohort and the DRF Medicare cohort. Racial composition was different ($p<0.001$); however, the 1.8% difference in percentage of white beneficiaries, although statistically significant, is not likely to be clinically or analytically significant.

Selected counties varied widely in size and had a mean population of 92,438 (range: 5,362–1,001,885). Nationally, DRF incidence in 2007 was 23.3/10,000 people age 65 and over. The national incidence of minor fractures was 16.4/10,000, whereas major fractures was 6.9/10,000, with minor to major ratio of 2.4:1. Distribution of major vs. minor fracture type was not significantly different in the analysis cohort ($p=0.47$, Table 3).

Slippery weather (slipperiness score of 5 or higher) was reported on at least 1 day by 83 of 100 selected airports. The mean number of days with slippery weather per county was 28.1 (range: 0–104). Slippery weather was most frequent in the winter months (December, January, and February) (Figure 2). Likewise, DRF incidence was highest in January and December (Figure 3, Table 4). ANOVA results indicate that the differences seen between fracture counts per month are significant ($p<0.0001$). Pairwise comparisons indicated that DRF counts in January, the month with the most slippery days, were significantly different ($p<0.05$) from April, May, June, July, August, September, October and November. Both minor and major fractures peaked in those months as well, but minor fractures showed more seasonality than major fractures (Figure 4). Grouping the months of December, January, and February together as the “winter” season, the IRR for DRFs in the winter is 1.2 (95% CI 1.14–1.26, $p<0.001$) indicating a 20% increased risk of fracture among Medicare beneficiaries across the United States during those months. Based on this adjusted estimation model, we predict that 100 excess fractures occurred every 8.5 days during the winter. Over 90 days of winter our model predicts an additional 1,060 DRFs occur in the US elderly compared to any other block of 90 days during the year.

Simple negative binomial regression models of daily DRF counts showed that risk of DRF increased with freezing rain (IRR = 1.24, $p=0.025$), snow and/or ice on the ground at the start of the day (IRR = 1.45, $p<0.001$), and average temperature 32°F (IRR = 1.35, $p<0.001$) (Table 5). When DRF counts were modeled separately for minor versus major DRF, freezing rain, snow and/or ice on ground, and average temperature 32°F increased risk of major DRF, whereas only snow and/or ice on ground and average temperature 32°F increased risk of minor fracture (Table 5).

Using the slipperiness score as a categorical variable in our DRF model, at a score of 5, 6, and 7 there is a significant increase in risk of DRF (Table 6, Figure 5). Owing to the substantially fewer days with scores of 7, the confidence interval is much wider; however, the result remains significant. Minor (isolated) DRFs, more likely due to slip and fall accidents, also occurred significantly more frequently on days with higher slipperiness scores (Table 7, Figure 5). Major DRFs did not significantly correlate with slipperiness score. Dichotomizing slipperiness score with ≤ 5 being a “slippery” day, the IRR for a slippery day is 1.14 (95% CI 1.08–1.20, $p<0.001$), indicating that the risk of sustaining DRF in this population is increased by 14% on a slippery day. Minor DRF had an IRR of 1.18 on days with scores of 5, 6, or 7 (95% CI 1.10–1.25, $p<0.001$), a risk increase of 18%. Major DRF did not increase significantly based on slipperiness score.

Discussion

DRFs are a major public health concern, especially when they occur in the elderly. The loss of function and additional challenges to independence can have devastating consequences.²³ Resources are devoted to identifying the best treatment for each fracture, and osteoporosis screening and other health interventions are made to help prevent additional fractures after a DRF.^{37, 38} However, very little has been done in specific DRF risk identification and prevention. Expanding on case-report evidence, numerous small studies have supported the theory that slippery weather, especially in the winter, results in higher occurrence of DRFs.^{24, 27} In this retrospective study of a much larger cohort from various climates and

regions across the United States, we have found significant evidence to support this weather-related fracture risk.

This study has identified a strong correlation between slippery weather and DRFs, especially “minor” fractures that are more likely due to falls. The separate elements of snow or ice on the ground, freezing rain, and freezing temperature, all had significant correlation with DRF occurrence. When these weather elements were combined into the slipperiness score, the regression models were also significant. This not only supports findings from the other cited studies, but also allows our results to be more transferrable to public health and prevention domains by providing an easily reproducible scale that helps predict fracture risk due to weather.

Many other factors affect walking safety and fracture risk aside from weather conditions, including shoe choice, distance of on-foot travel, sidewalk care provided by municipalities and homeowners, and others.^{12, 39} These complexities make pavement safety modeling more challenging than road modeling.^{36, 40} The slipperiness score used in this study, based on some of the scientific findings from the FMI, takes a more simplified approach to this public health and safety issue. Considering the ease with which a daily weather report could be translated into this slipperiness score, identifying and publicizing high-risk weather days can be implemented similar to air quality, UV, and icy road warning systems. Although the results from these warning systems have been mixed, when properly utilized they can affect change and health improvements for individuals.⁴¹

In studies evaluating elderly fall risk prevention, one of the major limitations to success is that some of the highest fall and DRF risk patients – those who are more mobile and athletic for their age group – do not perceive themselves at risk of falling.^{42, 43} Additionally, these “active elderly” prefer messages of health and independence.⁴² Using a slipperiness index to relay hazardous conditions might inform timely behavior change, and have success in fall and fracture prevention where other educational efforts have thus far been unsuccessful.

This study has limitations, the greatest being the ecological design and approach. Although our model attempted to control for any county-specific differences that would result in changes in fracture risk, without additional county or individual-level data, this analysis is limited in generalizability. The retrospective nature also limits the quality of our results. Much of the variation in DRF occurrence remains unexplained by this model, although this is not unexpected in a large, ecologic study. This is also an expected result as there are many other factors that result in distal radius fractures aside from weather, as evidenced by the relatively constant baseline fracture incidence most months throughout the year. Additionally, although data quality was rigorously checked and Medicare data are reliable, errors in historical weather reporting and in Medicare fracture capture and reporting cannot be ruled out. The slipperiness score was novel for this study and could not be formally validated. Although using the road safety data provided some face validity to the scale, we cannot exclude the possibility that these slippery days correlate with MVC or DRF incidence for other reasons.

Improved understanding of the relationship between trauma and weather conditions can be useful for resource allocation and provider preparedness.⁷ Additionally, slipperiness indices and alerts may be useful in the US, especially in urban areas where many people, including the elderly, travel on foot. Indices of ultraviolet radiation and wind chill and ozone alerts, for example, are used to raise awareness and inform changes in behavior. Warning of slippery conditions could be distributed via weather outlets in a similar manner. These warnings may affect change in walking behavior and precautions, resulting in reduced incidence of weather-related injuries and a corresponding reduction in healthcare expenditures.

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Appendix 1. Cities, airports, and counties selected for analysis

<u>City</u>	<u>Airport</u>	<u>County/Parish</u>
Birmingham, AL	Birmingham-Shuttlesworth International	Jefferson
Montgomery, AL	Montgomery Regional	Montgomery
Anchorage, AK	Ted Stevens Anchorage International	Anchorage Municipality [†]
Fairbanks, AK	Fairbanks International	Fairbanks North Star Borough [†]
Phoenix, AZ	Phoenix Sky Harbor International	Maricopa
Tucson, AZ	Tucson International	Pima
Fort Smith, AR	Fort Smith Regional	Sebastian
Little Rock, AR	Little Rock National	Pulaski
Los Angeles, CA	Los Angeles International	Los Angeles
San Diego, CA	San Diego International	San Diego
Colorado Springs, CO	Colorado Springs Municipal	El Paso
Denver, CO	Denver International	Denver
Bridgeport, CT	Sikorsky Memorial	Fairfield
New Haven, CT	Tweed New Haven Regional	New Haven
Dover, DE	Dover Air Force Base	Kent
Wilmington, DE	New Castle County	New Castle
Washington, DC	Washington Dulles International	Fairfax, Loudoun
Jacksonville, FL	Jacksonville International	Duval
Miami, FL	Miami International	Miami-Dade
Augusta, GA	Augusta Regional	Richmond
Atlanta, GA	Hartsfield-Jackson Atlanta International	Fulton, Clayton
Hilo, HI	Hilo International	Hawaii
Honolulu, HI	Honolulu International	Honolulu
Boise, ID	Boise	Ada
Nampa, ID	Magic Valley Regional	Twin Falls
Chicago, IL	O'Hare International	Cook, DuPage
Rockford, IL	Chicago Rockford International	Winnebago
Fort Wayne, IN	Fort Wayne International	Allen
Indianapolis, IN	Indianapolis International	Marion
Cedar Rapids, IA	Eastern Iowa	Linn
Des Moines, IA	Des Moines International	Polk
Topeka, KS	Philip Billard Municipal	Johnson

<u>City</u>	<u>Airport</u>	<u>County/Parish</u>
Wichita, KS	Wichita Mid-Continent	Sedgwick
Lexington, KY	Blue Grass	Fayette
Louisville, KY	Louisville International	Jefferson
Baton Rouge, LA	Baton Rouge Memorial	East Baton Rouge
New Orleans, LA	Louis Armstrong New Orleans International	Jefferson
Bangor, ME	Bangor International	Penobscot
Portland, ME	Portland International	Cumberland
Baltimore, MD	Baltimore-Washington International	Ann Arundel
Frederick, MD	Frederick Municipal	Frederick
Boston, MA	Logan International	Suffolk
Worcester, MA	Worcester Regional	Worcester
Detroit, MI	Detroit Metro Wayne County International	Wayne
Grand Rapids, MI	Gerald R. Ford International	Kent
Minneapolis, MN	Minneapolis-St. Paul International	Hennepin
St. Paul, MN	St. Paul Downtown	Ramsey
Gulfport, MS	Gulfport-Biloxi International	Harrison
Jackson, MS	Jackson-Evers International	Rankin
Kansas City, MO	Kansas City International	Platte
St. Louis, MO	Lambert-St. Louis International	St. Louis
Billings, MT	Billings Logan International	Yellowstone
Missoula, MT	Missoula International	Missoula
Lincoln, NE	Lincoln	Lancaster
Omaha, NE	Eppley Airfield	Douglas
Las Vegas, NV	McCarren International	Clark
Reno, NV	Reno-Tahoe International	Washoe
Manchester, NH	Concord Municipal	Merrimack
Rochester, NH	Skyhaven	Strafford
Atlantic City, NJ	Atlantic City International	Atlantic
Newark, NJ	Newark Liberty International	Essex, Union
Albuquerque, NM	Albuquerque International	Bernalillo
Las Cruces, NM	Las Cruces International	Doña Ana
Buffalo, NY	Buffalo Niagara International	Erie
New York, NY	John F. Kennedy International	Queens
Charlotte, NC	Charlotte/Douglas International	Mecklenburg
Raleigh, NC	Raleigh-Durham International	Wake
Bismarck, ND	Bismarck Municipal	Burleigh
Fargo, ND	Hector International	Cass
Cleveland, OH	Cleveland Hopkins International	Cuyahoga
Columbus, OH	Port Columbus International	Franklin
Oklahoma City, OK	Will Rogers World	Oklahoma
Tulsa, OK	Tulsa International	Tulsa
Eugene, OR	Eugene	Lane

<u>City</u>	<u>Airport</u>	<u>County/Parish</u>
Portland, OR	Portland International	Multnomah
Philadelphia, PA	Philadelphia International	Philadelphia, Delaware
Pittsburgh, PA	Pittsburgh International	Allegheny
Providence, RI	Theodore Francis Green Memorial State	Kent
Charleston, SC	Charleston International	Charleston
Columbia, SC	Columbia Metro	Lexington
Rapid City, SD	Rapid City Regional	Pennington
Sioux Falls, SD	Sioux Falls Regional	Minnehaha
Memphis, TN	Memphis International	Shelby
Nashville, TN	Nashville International	Davidson
Houston, TX	George Bush Intercontinental	Harris
San Antonio, TX	San Antonio	Bexar
Salt Lake City, UT	Salt Lake City International	Salt Lake
West Valley City, UT	Skypark	Davis
Burlington, VT	Burlington International	Chittenden
Essex, VT	Edward F. Knapp State	Washington
Norfolk, VA	Norfolk International	Norfolk city ²
Virginia Beach, VA	Newport News/Williamsburg International	Newport News city ²
Seattle, WA	Seattle-Tacoma International	King
Spokane, WA	Spokane International	Spokane
Charleston, WV	Yeager	Kanawha
Huntington, WV	Tri-State	Wayne
Madison, WI	Dane County Regional	Dane
Milwaukee, WI	General Mitchell International	Milwaukee
Casper, WY	Casper/Natrona International	Natrona
Cheyenne, WY	Cheyenne Regional	Laramie

¹ Alaska does not have counties. Instead, the most densely populated areas are divided into 18 boroughs.

² In Virginia all municipalities incorporated as cities are not included in counties and are independent cities.

Appendix 2. Results of regression models correlating slipperiness score and motor vehicle collisions

Motor vehicle collisions (MVCs) were used as a proxy measure for slippery conditions to add validity to this scoring system. The NBR model of MVCs showed slipperiness score to be significantly associated with the rate of MVC. In Ann Arbor, MI, the number of daily MVCs correlated to slipperiness score with an IRR of 1.11. This indicated that for each incremental increase in slipperiness score, the risk of MVC increased by 11%. Treating slipperiness score as a categorical variable, the risk of MVC increases between scores of 3 to 6. At a score of 3, the IRR is 1.43 ($p<0.001$) and reaches an IRR of 2.26 at a score of 6 ($p<0.001$). Only 1 day had a slipperiness score of 7 and was therefore not significant in the model.

Running similar models for Wayne County, Michigan, slipperiness score again correlated with increased risk of MVC between scores of 3 to 7. For a score of 3, IRR of MVC increased from 1.09 ($p<0.001$) to 1.86 on days with a score of 7 ($p<0.001$).

Figure 1.
US map showing location of selected airports

Figure 2.
Number of selected airports reporting slippery weather, by day, for 2007

Figure 3.
Number of distal radius fractures per day, by month, in the analysis cohort of Medicare beneficiaries in 2007

Figure 4.

Incidence Rate Ratio of DRF by slipperiness score, as compared to slipperiness score of 0. The dotted line at 1 is the reference for no difference. Slipperiness scores of 5, 6, and 7 resulted in a significantly increased risk for DRF.

Figure 5.

IRR of isolated (minor) DRF by slipperiness score. The dotted line at 1 is the reference for no difference. Slipperiness scores of 5, 6, and 7 resulted in a significantly increased risk for DRF.

Table 1

ICD-9-CM codes and Current Procedural Terminology (CPT) codes indicating treatment of distal radial fracture.

ICD-9-CM codes	
fracture, lower end of forearm, unspecified	813.40
Colles fracture	813.41
other fracture of distal end of radius (alone)	813.42
fracture, radius with ulna, lower end	813.44
torus fracture of radius (alone)	813.45
CPT codes for DRF treatment	
external fixation	20690, 20692
closed treatment	25600, 25605, 29065, 29075, 29085, 29105, 29125, 29126
percutaneous pinning	25606
internal fixation	25607, 25608, 25609

Table 2**Slipperiness Score (SS) Calculator**

Weather Condition	Added to Score
1. Temperature 32°F	+1
2a. Presence of mild weather events * (rain, drizzle, etc.) OR	+1
2b. Presence of harsh weather events ** (snow, freezing rain, etc.)	+2
3. Presence of snow/ice on ground at start of day	+1
4a. Precipitation on ground that day with water equivalent 0.01 in OR	+1
4b. Precipitation on ground that day with water equivalent > 0.01 in	+2
5. Max wind speed 24 mph	+1
Total = SS [0–7]	

* mild weather events: rain, mist, drizzle, showers, thunderstorms

** harsh weather events: freezing drizzle, freezing fog, freezing rain, hail, snow pellets, ice pellets, snow grains, snow, glaze, drifting snow, thunderstorm hail, thunderstorms with snow pellets, thunderstorm snow

Table 3

Demographic characteristics of analysis cohort, Medicare distal radius fracture cohort, and 2007 US Population Estimates for ages 65 years and over

		Analysis Cohort	Medicare Cohort	US*
Total		21,507	85,868	37,825,711
Gender[#]				
	Female	85.1%	85.2%	50.9%
	Male	14.9%	14.8%	49.1%
Age (years)^{\$}				
	65–69	18.3%	18.1%	29.0%
	70–74	18.3%	18.7%	23.1%
	75–79	21.1%	21.4%	19.6%
	80–84	21.7%	21.0%	15.0%
	85–89	14.2%	14.1%	8.9%
	90–94	5.3%	5.5%	3.5%
	95–99	1.2%	1.2%	0.9%
	^100+	0	0	0.1%
Race⁺				
	White	94.0%	95.80%	86.9%
	Non-White	5.8%	4.10%	13.1%
	Unknown	0.1%	0.1%	0
Fracture Type[%]				
	Minor	70.3%	70.0%	
	Major	29.7%	30.0%	

* 2007 National Characteristics Intercensal Population Estimates File, Source: U.S. Census Bureau, Population Division, Release Date: September 2011.

^ This age category was excluded from the Medicare and Analysis cohorts in this study

Gender distribution between analysis cohort and Medicare cohort is not significantly different (Pearson's Chi-square test, p=0.82)

\$ Age distribution between analysis cohort and Medicare cohort is not significantly different (Kolmogorov-Smirnov test, p=0.65)

+ Racial composition of analysis cohort and medicare cohort is significantly different (Pearson's Chi-square test, p<0.001)

% Minor fracture is a DRF code that occurs with no other trauma codes. Major fracture codes have concurrent additional trauma codes, including any other fracture, neurologic injury, solid organ injury, pneumothorax, and/or hemothorax. Fracture type distribution between analysis cohort and Medicare cohort is not significantly different (Pearson's Chi-square test, $p=0.47$)

Table 4

Number of distal radius fractures that occurred in each month in the analysis cohort

Month	Fractures per month	Fractures per day
January	2258	72.8
February	1704	60.9
March	1893	61.1
April	1546	51.5
May	1802	58.1
June	1734	57.8
July	1715	55.3
August	1697	54.7
September	1672	55.7
October	1750	56.5
November	1655	55.2
December	2081	67.2

Table 5

Results for regression models evaluating the effects of specific weather events.

	IRR	p-value *	95% CI
Temp 32°F			
Total DRF	1.35	< 0.001	1.19–1.54
Minor Fractures	1.40	< 0.001	1.22–1.61
Major Fractures	1.33	< 0.001	1.13–1.56
Snow or Ice on Ground at Beginning of Day			
Total DRF	1.45	< 0.001	1.25–1.68
Minor Fractures	1.50	< 0.001	1.28–1.76
Major Fractures	1.41	< 0.001	1.20–1.66
Freezing Rain			
Total DRF	1.24	0.025	1.03–1.49
Minor Fractures	0.14	> 0.080	0.95–1.46
Major Fractures	1.43	0.006	1.10–1.84

* Significance set at $p < 0.05$. The row shaded in grey did not reach statistical significance.

Table 6

Regression results correlating slipperiness score and IRR of distal radius fracture

Slipperiness Score	IRR	95% CI	p-value*
1	0.983	0.944 1.024	0.419
2	0.998	0.953 1.044	0.918
3	0.972	0.929 1.017	0.219
4	0.957	0.908 1.009	0.102
5	1.088	1.010 1.173	0.027
6	1.122	1.026 1.227	0.011
7	1.300	1.098 1.540	0.002

* Significance set at $p < 0.05$. The rows shaded in grey did not reach statistical significance.

Table 7

Regression results correlating slipperiness score and risk of isolated (minor) distal radius fractures

Slipperiness Score	IRR	95% CI	p-value*
1	1.001	0.953 1.051	0.967
2	1.024	0.970 1.082	0.389
3	1.009	0.956 1.066	0.733
4	1.021	0.959 1.087	0.516
5	1.152	1.053 1.259	0.002
6	1.198	1.077 1.332	0.001
7	1.386	1.133 1.696	0.002

* Significance set at $p < 0.05$. The rows shaded in grey did not reach statistical significance.