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Age-Based Incidence of Dens Fracture Has Unimodal Distribution Rather Than Commonly Claimed Bimodal Distribution

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Background: Type-II dens fractures have long been described in the literature as occurring in a bimodal distribution, peaking in young adulthood as well as in older adulthood; however, the origin of this claim is unclear. The primary goal of this study was to examine the incidence of type-II dens fractures and assess for bimodality.

Methods: This is a retrospective cross-sectional review of the National Trauma Data Bank (NTDB) records on traumatic type-II dens fractures between October 2015 and December 2016. Rates were obtained from the NTDB, and the incidence per 100,000 was ascertained by utilizing U.S. Census data from 2016. Subgroupings by gender and Black or White race were also examined.

Results: Dens fractures occur unimodally, peaking around 89 years of age overall, skewed left by high rates in older White adults. The Black subgroup demonstrated trimodality, with the fracture incidence peaking at 25, 62, and 82 years of age. Rates among Black and White patients were similar until age 65, after which dens fractures occurred disproportionately in White patients. Fractures prior to age 75 occurred predominantly in men.

Conclusions: The evidence derived in this study challenges the common belief that type-II dens fractures occur bimodally across the entire population. However, there remains utility in considering younger and older patients as distinct groups for the purposes of management.

The dens is an osseous protuberance of the axis (second cervical vertebra [C2]) that articulates with the atlas (first cervical vertebra [C1]) above. This articulation is important because it is responsible for 50% of the entire axial rotation and 10° to 20° of sagittal flexion-extension of the cervical spine. Therefore, fractures of the dens have a substantial adverse effect on the ability to maintain pain-free motion of the cervical spine. According to recent literature, the fracture may also have a significant detrimental effect on mortality[1,2].

The most commonly used classification of dens fractures is the Anderson and D'Alonzo system[3]. Type I is an oblique avulsion at the superior end of the dens, type II is a fracture at the base of the dens, and type III involves the C2 vertebral body. While most type-I and type-III dens fractures are considered biomechanically stable and heal readily with external immobilization, the optimal treatment and outcomes for type-II dens fractures remain topics of interest[4]. Although external immobilization using a rigid cervical collar is associated with higher rates of nonunion compared with surgical fixation for type-II fractures, it is still commonly used, especially in the elderly patient population[5].

Literature on the subject of type-II dens fractures makes frequent reference to the bimodal nature of these injuries, suggesting that they are caused by high-energy mechanisms such as motor vehicle collisions among young adults while low-energy mechanisms such as falls constitute the majority of cases in the elderly[6-15]. In fact, the bimodality of dens fractures has been so frequently cited throughout the literature that some authors view it as common knowledge and forgo providing any references to support it[5,7,10,12]. When articles are cited, an in-depth review often will reveal that they do not actually claim bimodality but rather show a wide distribution of ages among affected patients[3,16-22]. To the best of our knowledge, only 1 article, published in 2013, explicitly reports bimodality in its data[23]. However, that study was

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limited to 22 patients, and there was no statistical analysis of modality; instead, patients were simply grouped based on ages above or below 70 years. Furthermore, although a previous study documented the patient-age distribution of all cervical fractures and dens fractures in general, it did not investigate dens fractures in distinct demographic groups[24]. A study that did examine demographic data made no conclusive claims about modality[25].

The exact origin of the bimodality claim is unclear based on a review of the literature. In this study, we reconsider the commonly accepted notion of bimodality of type-II dens fractures by examining the age distribution of patients with these injuries using a national database.

Materials and Methods

This is a retrospective cross-sectional review of the records on traumatic type-II dens fractures, including polytrauma cases, in the National Trauma Data Bank (NTDB) from October 2015 to December 2016. The NTDB contains standardized, de-identified data from >900 U.S. trauma centers. It includes different types of trauma hospitals, ranging up to level 4, as well as community hospitals for which "not applicable" was entered into the field for "level." This inclusion ensures that the data encompass a broader representation, including smaller community hospitals. The inclusion criterion consisted of any International Classification of Diseases, 10th Revision (ICD-10)

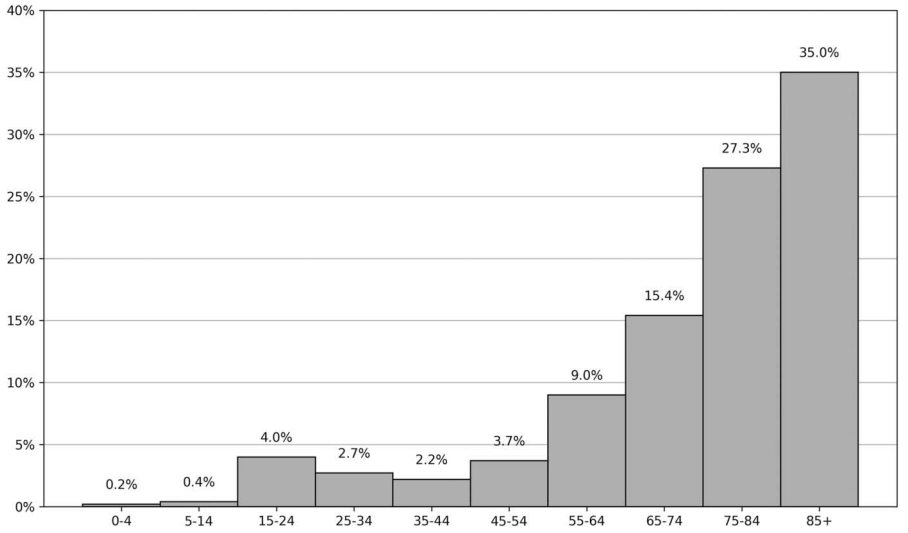

Fig. 1-A

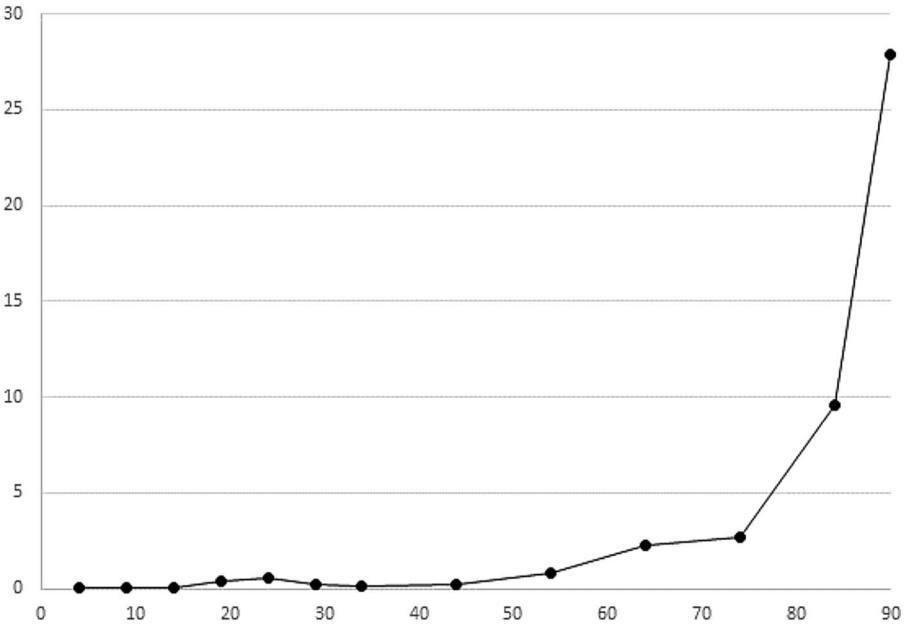

Fig. 1-B

Fig. 1-A Histogram showing the percentages of all type-II dens fractures by the decade of age. **Fig. 1-B** Estimated numbers of type-II dens fractures per 100,000 patients using census data. Note that the values on the x axis represented by each data point are the upper limit of the age range.

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code of S12.11 (type-II dens fracture) or a more specific code for the fracture. Patients with an ICD-10 code indicating a penetrating injury as well as those with missing data for variables of interest were excluded. Patient data including age, race, and gender were extracted from the database using custom Python (2020, version 3.9) code. Institutional review board approval was obtained. U.S. Census data from 2016 were used to provide estimates of the number of fractures per 100,000 individuals[26,27]. A histogram was constructed to visualize the data by grouping patients into bins (<5, 5 to 9, 10 to 14, 15 to 19, 20 to 24, 25 to 29, 30 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, and ≥85 years). Multimodality was assessed using the Modes() function of the LaplacesDemon package for Bayesian analysis, in R (version 4.2.1)[28,29]. This study was not funded by outside sources.

Results

There were 1,612,873 trauma cases logged in the NTDB during the specified time frame; 5,007 patients with a traumatic type-II dens fractures met the inclusion criteria for this study, after 14 patients were removed due to having a penetrating injury. Ages ranged from 1 to ≥89 years, after which exact ages were not recorded in the NTDB for patient privacy (n = 852). A value of 90 years was substituted for these individuals.

Overall Data

Visual inspection of the histogram in Figure 1-A strongly suggests a unimodal distribution of type-II dens fractures, which was confirmed by analysis using R, with a leftward skew. The Modes function returned a single mode at 88.6 years of age. The ≥85-year age group accounted for over a third of type-II dens fractures, while patients ≥65 years old accounted for over three-quarters of these fractures (Fig. 1-A). Prior to age 55, dens fractures occurred at rates of <1 case per 100,000. They occurred at a rate of 2.3 cases per 100,000 in the 60 to 64-year age group, 2.7 per 100,000 in the 65 to 74-year age group, 9.6 per 100,000 in the 75 to 84-year age group, and 27.9 per 100,000 in the ≥85-year age group (Fig. 1-B). The number of cases per 100,000 was dramatically higher in the 75 to 84 and ≥85-year age groups due to a combination of increased incidence and a lower number in the population in these age ranges. Prior to 55 years of age, each age group accounted for <4% of fractures, with most closer to 2% or less. The 20 to 24-year age group had the highest rate of fractures (2.4% of all type-II dens fractures) among patients younger than 55 years.

Data By Gender

Men (n = 2,436, 48.7%) and women (n = 2,571, 51.3%) were separated into subgroups. As seen in Figure 2, men accounted for the majority of dens fractures in the <75-year age group. Thereafter, dens fracture rates significantly increased in women, so that they predominated in women in the 75 to 84 and ≥85-year age groups. Fractures occurred bimodally in men at ages 21.7 and 86.6 years, but were unimodal in women at age 89.1 years.

Data By Race

Most patients were White (n = 4,407, 88.0%). The next largest racial group was Black (n = 260, 5.2%). Asian, Native Hawaiian or Other Pacific Islander, and American Indian patients constituted the remainder of the population, with ≤51 individuals per group. Due to the low numbers of subjects, these 3 racial groups were not included in the analysis, as were the 260

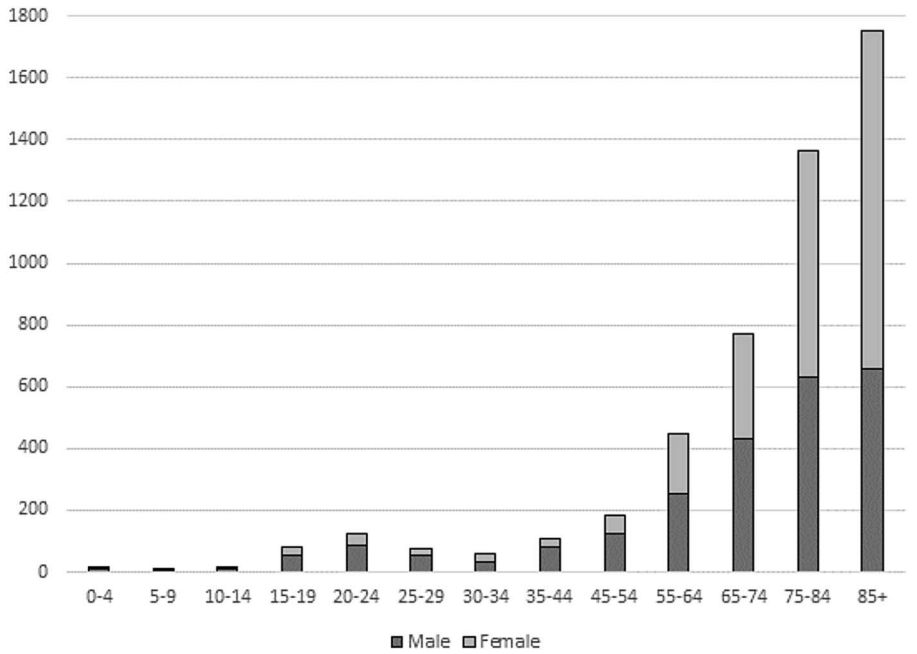

Fig. 2

Relative contributions of women and men to the number of type-II dens fractures in each age group.

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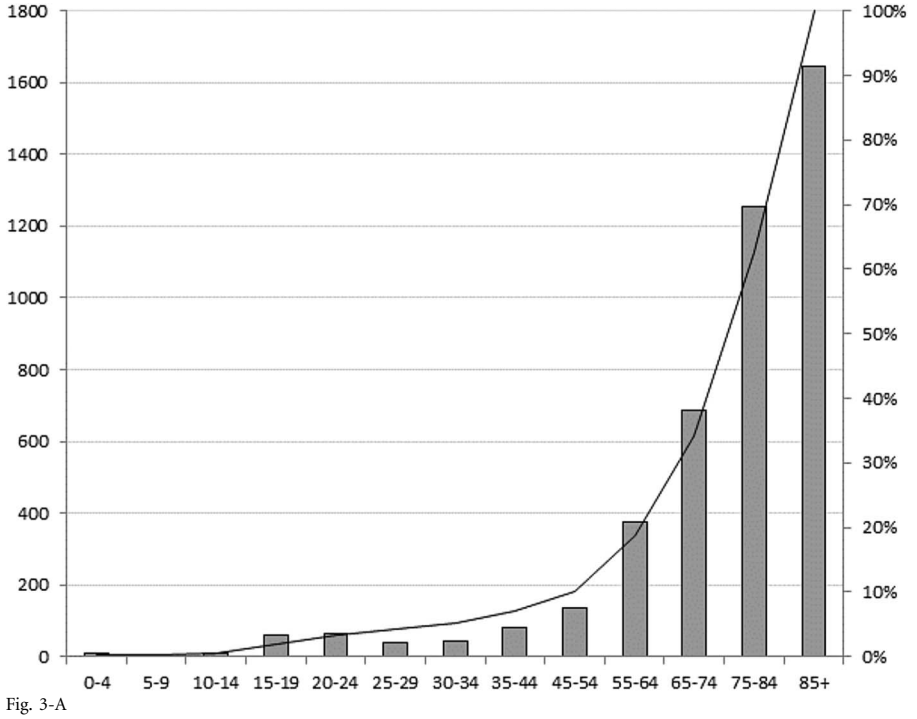

Fig. 3-A

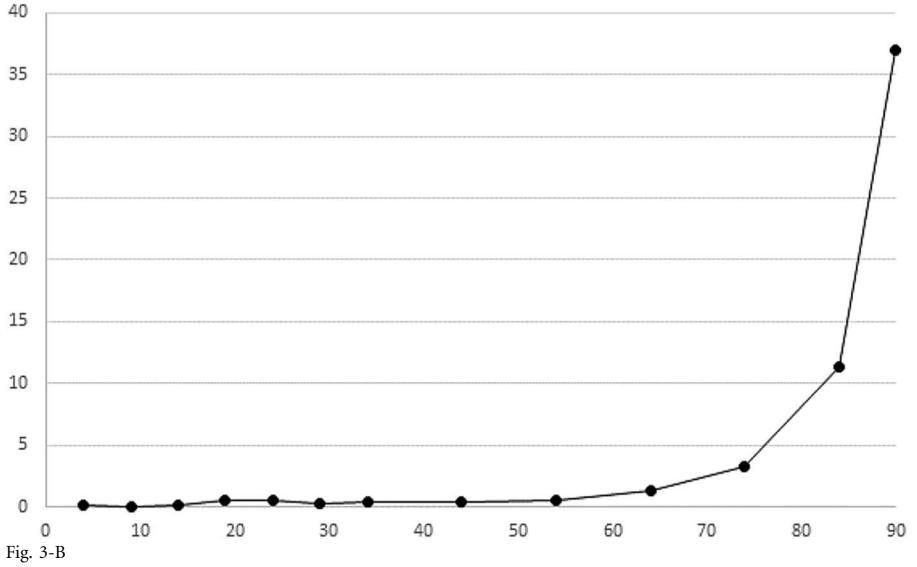

Fig. 3-B

Fig. 3-A Raw data for type-II dens fractures in White patients from the NTDB, including histogram data and cumulative percent data. **Fig. 3-B** Estimated number of type-II dens fractures per 100,000 White individuals using census data. Note that the values on the x axis represented by each data point are the upper limit of the age range.

patients whose race was unknown or identified as a race other than the 5 races included in the census data. The defined age groups used for the overall study population were also used for the racial subgroupings. Raw histogram data as well as an estimate of the number of fractures per 100,000, utilizing census data for White patients and Black patients, are shown in Figures 3-A through 4-B. Dens fractures among White patients were unimodal (mode = 88.7 years of age); however, dens fractures were trimodal among Black patients (modes = 25.3, 62.4, and 82.2 years of age). When the estimated cases per 100,000 were superimposed on graphs with the same axis dimensions (Fig. 5), the rates among Black and White patients were seen to be nearly identical until age 65 years, at which point White patients had a significant increase in fractures compared with Black patients—2.6 times the rate in the following decade, 4.6 times the rate in the subsequent decade, and then 4.5 times the rate in adults over 85 years of age (Table I).

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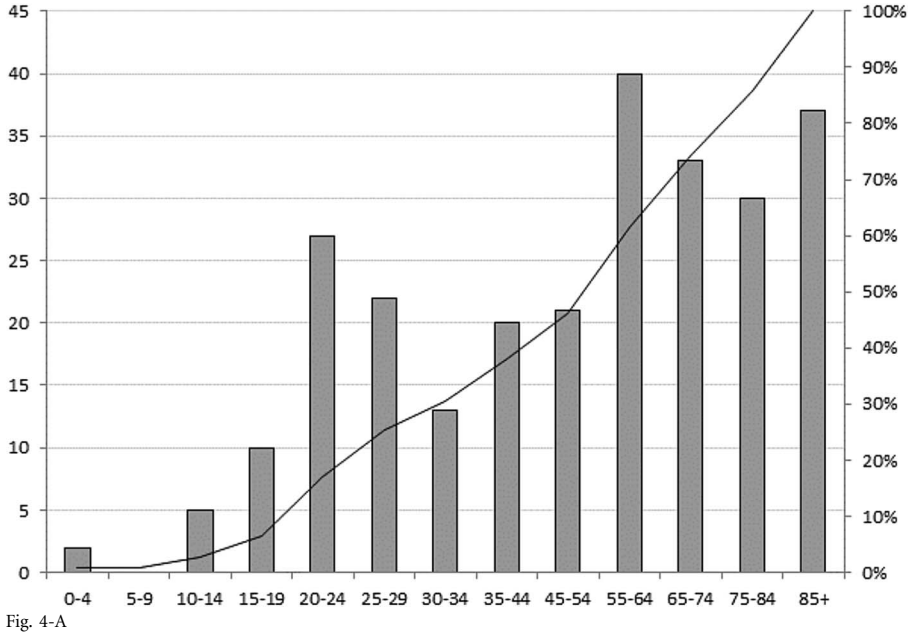

Fig. 4-A

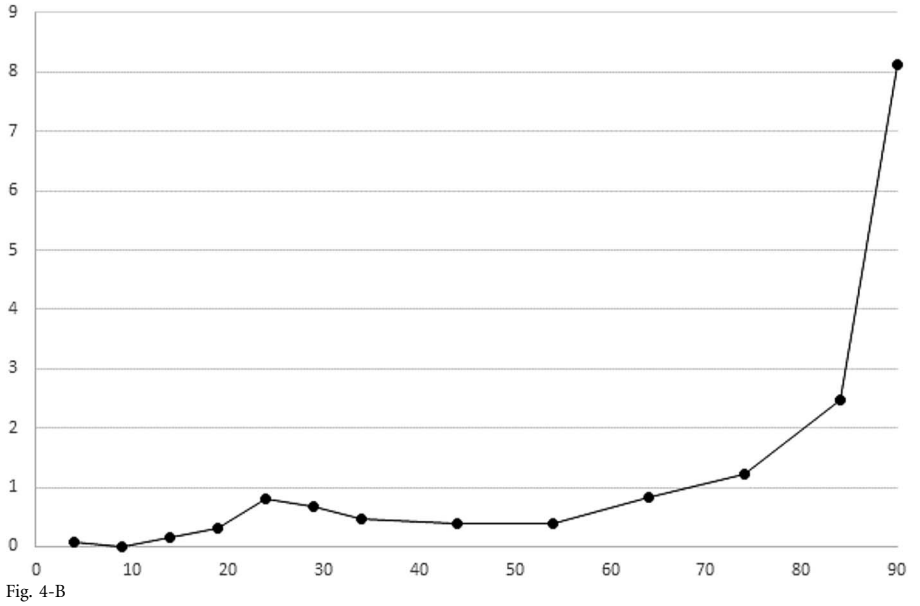

Fig. 4-B

Fig. 4-A Raw data for type-II dens fractures in Black patients from the NTDB, including histogram data and cumulative percent data. **Fig. 4-B** Estimated number of type-II dens fractures per 100,000 Black individuals using census data. Note that the values on the x axis are the upper limit of the age range that each data point represents.

Discussion

There are 4 major takeaways from the results of this study. First, dens fractures occur in a unimodal distribution when the population is considered as a whole. Second, the majority of dens fractures that occur prior to the age of 75 years occur in men. Third, fractures occur trimodally in Black patients and bimodally in men. Finally, geriatric White patients sustain dens fractures at far higher rates compared with Black patients.

Claims of bimodality with regard to type-II dens fractures have been so frequently repeated that it became "common knowledge" and the origin of these claims was obscured. If dens fractures did occur in a bimodal distribution in the past, it is possible that increased survivorship into very late adulthood has led to a unimodal distribution[30]. Future research could compare incidence and modality among age groups over a longer period of time than was studied in our review. It is also possible that there was no research-based origin to this bimodality claim, but rather different attitudes about treating differently aged groups of patients led practitioners to believe type-II dens fractures were occurring at 2 modes. Indeed, there is utility in

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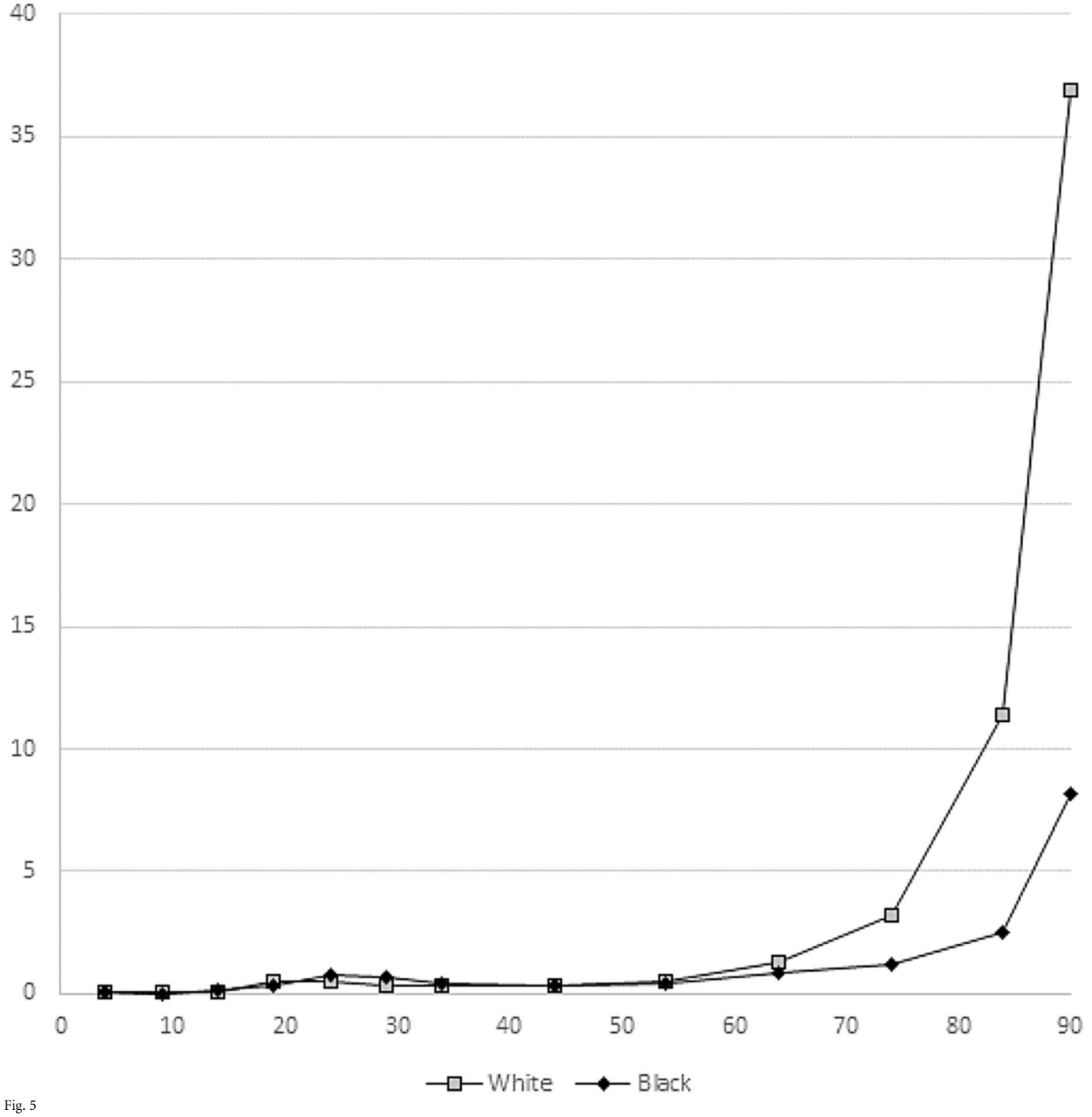

Fig. 5

Estimated numbers of type-II dens fractures per 100,000 White patients and per 100,000 Black patients on the same axis, demonstrating significantly higher rates in White patients over the age of 65 years.

approaching young patients and elderly patients with type-II dens fractures differently, given that certain treatment options such as halo vests portend worse outcomes for the elderly while others such as early operative intervention may improve 1-year mortality[2,31,32].

The only evidence of bimodality in this study occurred in the male subgroup, peaking when the patients were in their 20s and 80s; however, these findings were obscured when the analysis was performed in the 2 racial subgroups. Trimodality occurred in the Black subgroup, with peaks in the patients' 20s, 60s, and 80s. This claim could benefit from exploration of other data sets, given our relatively small sample size. The second mode in Black patients occurred >2 decades earlier than the mode in White patients (62.4 and 88.7 years, respectively). It is possible that bone mineral density is less of a contributing

TABLE I Estimated Cases of Type-II Dens Fracture per 100,000 Individuals and the Ratio Between White and Black Individuals

Age *(yr)*	All Races	Black	White	Ratio of White to Black
0-4	0.06	0.07	0.09	1.3
5-9	0.02	0.00	0.04	—
10-14	0.08	0.16	0.08	0.5
15-19	0.38	0.32	0.54	1.7
20-24	0.55	0.79	0.55	0.7
25-34	0.17	0.67	0.30	0.4
35-44	0.15	0.46	0.35	0.8
45-54	0.25	0.38	0.36	0.9
55-59	0.84	0.39	0.49	1.3
60-64	2.27	0.83	1.28	1.5
65-74	2.70	1.23	3.24	2.6
75-84	9.60	2.48	11.37	4.6
≥85	27.90	8.13	36.93	4.5

factor in the etiology of dens fractures among Black patients compared with White patients[33]. Higher mortality rates and consequently lower average life expectancies may contribute to the lower mode for dens fractures in geriatric Black patients, although the disparity in life expectancies is too small to be the root cause[34]. According to a recent study, older White adults are not more likely to fall than older Black adults[35]. Additional research addressing the reasons for the discrepancy in dens fracture rates among different populations is needed.

Limitations of this database study include data entry errors as well as incomplete or missing data. Specific to this database and study, some adults had ages recorded as ≥89 years, with their actual ages obscured for privacy; they were presumed to be age 90 in our study. This assumption, if valid, underestimates the true mode, so the reported values should be taken as an estimate. With regard to the racial subgroup analysis, this study is limited by a relatively smaller sample of Black patients compared with White patients, which does not reflect nationwide demographics. Small sample sizes for other races prohibited meaningful analysis of those racial subgroups. These differences in sample size may accurately reflect real-world differences in dens fracture rates or they may reflect a difference in the way data are entered into the NTDB; therefore, evaluation of trimodality among Black patients using another data set may be warranted. Finally, statistical testing for modes is an ill-defined endeavor with only a few options available in R. The LaplacesDemon package was selected because its Modes function provided both the number of modes per data set and their values, whereas other functions merely stated whether the data were unimodal or not. Variation between methods may occur.

Furthermore, it is important to recognize that the findings presented in this study are based on data obtained from the NTDB. While the NTDB provides a valuable source of information, external validation of our results is essential to enhance the generalizability and reliability of our conclusions. Therefore, we encourage future research efforts to replicate our analysis using independent data sets or research studies. Such external validation would not only strengthen the validity of our findings but also contribute to a more comprehensive understanding of the demographic patterns and factors influencing dens fracture rates.

Conclusions

There is strong evidence that type-II dens fractures occur in a unimodal distribution, peaking around the age of 89 years. Subgroup analysis suggested that Black patients may experience a trimodal incidence. Most dens fractures prior to age 75 years occur in men. The evidence presented challenges the common belief that type-II dens fractures occur bimodally; however, there is still utility in considering younger and older patients as distinct groups for the purposes of management. ■

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