

A Decade of Geriatric Traumatic Brain Injuries in Finland: Population-Based Trends

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Abstract

Background: We investigated trends of traumatic brain injury (TBI)-related hospitalisations, deaths, acute neurosurgical operations (ANO), and lengths of hospital stay (LOS) in patients aged ≥ 70 years in Finland using a population-based cohort.

Methods: Nationwide databases were searched for all admissions with a TBI diagnosis as well as later deaths for persons ≥ 70 years of age during 2004–2014.

Results: The study period included 20,259 TBI-related hospitalisations (mean age=80.7 years, men=48.9%). The incidence of TBI-related hospitalisations was 283/100,000 person-years with an estimated overall annual increase of 2.9% (95%CI 0.4–5.9%). There was an annual decrease of 2.2% in in-hospital mortality (IHM) in men (95%CI:0.1–4.3%), with no change in women or overall. There was an annual decrease of 1.1% in odds for ANOs among hospitalised overall (95%CI:0.1–2.1%) and of 1.4% in men (95%CI:0.0%–2.7%), while no change was observed in women. LOS decreased annually by 2.5% (95%CI:2.1–2.9%). The incidence of TBI-related deaths was 70/100,000 person-years with an estimated annual increase of 1.6% in women (95%CI:0.2–2.9%), but no change in men or overall. Mean ages of TBI-related admissions and deaths increased ($p < 0.001$).

Interpretation: The incidence rate of geriatric TBI-related hospitalisations increased, especially in women, but LOS and the rate of ANOs among hospitalised decreased. The overall TBI-related mortality remained stable and IHM decreased in men, while in women, the overall mortality increased, and IHM remained stable. However, the overall incidence rates of TBI-related hospitalisations and deaths, and the number of cases of IHM were still higher in men.

Key points

- Older citizens are the fastest growing age group worldwide.
- The median age of patients with TBI has nearly doubled since the 1980s in high-income countries.
- We studied the impact of ongoing societal and demographic changes in Finland on geriatric traumatic brain injuries. • The incidence rate of geriatric TBI-related hospitalisations has increased.
- Traumatic brain injuries in older women are on the rise and seem to have more severe consequences than in men.

Introduction

Traumatic brain injury (TBI) is a frequent cause of injury-related death and disability world-wide.[1,2] The median age of patients with TBI has nearly doubled since the 1980s in high-income countries.[3] In Finland, the age-adjusted incidence of TBI has tripled from 1970 to 2011[4] and the incidence rate of TBI-related deaths is one of the highest in Europe.[2,5]

The majority of TBIs in Europe are mild in severity[6], and this applies also to older patients[7]. Generally, the mortality and morbidity following TBI in older adulthood is higher compared to younger age groups, and older people individuals experience slower and often more unfavourable recovery.[8] Notably, trauma centres often have age-based cut-offs for intensive care management and neurosurgical interventions [9] which may represent a self-fulfilling prophecy. Given the growing burden of geriatric TBI and the lack of population-based studies in examining temporal changes in these events in relation to the increased TBI-related hospital admissions in older patients, there is an urgent need to conduct quality research on this subpopulation that is highly under-represented in the TBI literature.[8] We therefore investigated the incidence and trends of hospitalisations, deaths, acute neurosurgical operations (ANO), length of hospital stays (LOS), and in-hospital mortality (IHM) in patients with TBI aged 70 years and older in Finland.

Materials and Methods

Study population and data search

The Care Register for Health Care (held by National Institute for Health and Welfare or THL, Helsinki, Finland), a mandatory database for all public health care hospital discharges in Finland, was searched for all admissions with a TBI diagnosis (ICD-10 codes S06.*) for patients ≥ 70 years of age between January 1, 2004 and December 31, 2014. Information on ANOs, LOSs, and IHMs are included in the register's discharge data. All hospitals in Finland that provide care for acute TBIs necessitating acute head imaging, were included in the search. Hospital transfers related to a particular episode of a hospitalisation were combined as one admission. One admission per patient per calendar year was included. General population demographic data was obtained from Statistics Finland (Helsinki, Finland). The background population at risk consisted of 7,149,803 person-years.

In Finland, all death certificates include the cause of death labelled with an ICD-10 code. All death certificates are checked and approved (or sent back for corrections) by medically trained medicolegal officers of THL and collected automatically into a mandatory database held by the Statistics Finland. We searched this nationwide database covering all deaths in Finland for all deaths with acute TBI (ICD-10 codes S06.*) in persons ≥ 70 years of age during 2004–2014. Skull fractures (ICD-10 codes S02.*) were identified from TBI admissions and deaths. The person-years of each study year were estimated by population at the end of each year. IHM was defined as death during a hospitalisation episode.

The ANOs according to the Nordic Medico-Statistical Committee (NOMESCO) classification[10] included in the search were AAD00, AAD05, AAD10, AAD12, AAD15, AAD30, AAD40, AAF00, AAK80. Of these procedure types, AAD00,

AAD05, and AAD15 include a major craniotomy and acute hematoma evacuation, whereas AAD10 and AAD12 include a chronic hematoma evacuation via a mini-invasive burr hole.

The study was approved by THL (permission no. THL/1484/5.05.00/2017) and Statistics Finland (TK53-1410-15).

Statistical analysis

Differences in continuous variables were analyzed with the t-test. The associations between, i) age, gender, and study year, and ii) the incidence rate of TBI-related hospitalisations and deaths were studied with negative binomial regression modelling with and without being adjusted with age and gender.

For ANOs, all operation types were pooled. The incidence rate of ANOs in admitted TBI patients was studied with logistic regression model and the trends of ANOs were assessed with negative binomial regression. The trends in IHM were studied with Cox regression using both univariate and multivariate models. LOS was studied with linear regression model (log-transformed and standardized dependent variable) and assessed also with being adjusted with age, gender, and a possible ANO during a hospitalisation episode. Significance was inferred at 5%. The SAS system version 9.4 (SAS Institute Inc., NC, USA) and GraphPad Prism version 8.0 (Graphpad Software, CA, USA) were used for the statistical analyses.

Results

The study period included 7,149,803 person-years, 20,259 TBI-related hospital admissions (mean age=80.7 years, men=48.9%), 4,979 ANOs, and 4,988 TBI-related deaths (mean age=82.3 years, men=53.5%) of which 1,610 (32%) occurred during the hospitalisation related to TBI in patients aged 70 years and older in Finland. In TBI-related deaths, TBI was an underlying cause of death in 82.7% of cases and contributing/immediate cause of death in 17.3% of cases. Skull fractures were present in 3.7% of cases of TBI-related admissions and in 4.1 % of cases of TBI-related deaths. Mean ages of TBI-related admissions and deaths increased during the years 2004–2014 ($p<0.001$).

Incidence and annual trends of traumatic brain injury-related hospital admissions and deaths (Tables 1A and 1B)

The incidence of TBI-related hospital admissions was higher in males than females. The estimated overall annual increase in the incidence rate of hospital admissions was 2.9% (95% CI:0.4–5.9%, $p=0.047$), significant also when adjusted with age and gender. The estimated increase in the incidence rate of admissions was 2.6 % in men (95% CI:2.0–3.3%, $p<0.0001$) and 3.8% in women (95% CI:1.5–7.6%, $p<0.0001$) when adjusted with age. Among both genders, the incidence was lowest in the age group of 70–74 years with steep increases towards the older age groups with an exception of the two oldest age groups among women (Table 1A).

The incidence of TBI-related deaths was higher in males than females. There was an estimated annual increase in TBI-related deaths of 1.6% in women (95% CI:0.2–2.9%), but no change in men or overall as the analyses were adjusted with age and/or gender. The association was similar in different age-groups (interaction $p=0.243$), and in both genders

(interaction $p=0.819$). Among both genders, the incidence was lowest in the age group of 70–74 years again with steep increases towards the oldest age group.

Rate and annual trends of acute neurosurgical operations (Figure 1)

There were 3,120 (63%) ANOs performed on males and 1,859 performed on females. The most common procedure type was evacuation of chronic subdural hematoma (78%, $n=3,922$) followed by evacuation of acute subdural hematoma (18%, $n=906$) and evacuation of traumatic intracerebral hematoma (2%, $n=121$). Of the 2,547 ANOs that were performed on patients ≤ 80 years of age, 74% were mini-invasive chronic hematoma evacuations ($n=1,887$) and 22% were craniotomies with acute hematoma evacuation ($n=694$). Among patients ≥ 80 of age, 89% ($n=2,164$) of ANOs were mini-invasive chronic hematoma evacuations and 15% ($n=375$) were craniotomies with acute hematoma evacuation.

Of those patients who were hospitalized due to TBI, overall 25% (95% CI:23.5–25.9%) underwent an ANO, while the figure was 32% in men (95% CI:30.0–33.3%) and 18% in women (95% CI 16.9–19.2%). There was an annual decrease of 1.1% in odds for ANOs among hospitalized overall (95% CI:0.1–2.1%) and the decrease remained significant after adjusting with age and gender. The decrease in odds was 1.4% in men (95% CI:0.0%–2.7%), while no change was observed in women. In case of men, the decrease was not significant when adjusted with age.

Rate and annual trends of in-hospital mortality (Figure 2)

Of the in-hospital deaths, 859 occurred in males and 751 in females. Of those who were hospitalized because of TBI, 7.9% (95% CI:7.5–8.7%) died during the admission, and the figure was 8.7% in men (95% CI:7.7–10%) and 7.2% in women (95% CI:6.7–7.9%). There was an annual decrease of 2.2% in IHM in men (95% CI:0.1–4.3%), with no change in women or overall, also when adjusted for age and/or gender

Rate and annual trends of in-hospital length of stay

The mean overall LOS was 7.1 days (95% CI:6.1–7.5 days), whereas the mean LOS in men was 7.6 days (95% CI:7.1–8.1 days), and in women 6.6 days (95% CI:6.2–7.0 days). The overall LOS decreased annually by 2.5% (95% CI:2.1–2.9%). The decreases remained significant after adjusting with age, gender, and a possible ANO during the hospitalisation episode.

Discussion

In this population-based study, we investigated rates and trends of TBI-related hospitalisations, deaths, ANOs, IHM, and LOS in patients aged ≥ 70 years in Finland during the years 2004–2014. We found that the incidence of geriatric TBI-related hospitalisations increased, but LOS and the rate of ANOs among hospitalised decreased. In-hospital and overall TBI-related mortality remained mostly stable. Mean ages of TBI-related admissions and deaths increased during the study period. The rise in the incidence rate of TBI-related hospitalisations was more pronounced in women. TBI-related mortality remained stable and IHM decreased in men, while in women, TBI-related mortality increased and IHM

remained stable. However, the overall incidence rates of TBI-related hospitalisations and deaths, and the number of cases of IHM were still higher in men.

Older citizens are the fastest growing age group worldwide.[11] The growth of the older population has multiple implications on society and its healthcare system. The theoretical premise for this study was to examine the impact of ongoing societal and demographic changes in the Finnish society on geriatric TBI.

During the years 2004–2014, the incidence rate of TBI-related hospitalisations was 283.34 per 100,000 person-years with an annual increase of 2.9% among older people in Finland. An earlier Finnish study reported somewhat lower incidence rates, but an increase of 59% in the hospitalisations due to TBI in patients of same age during 1991–2005 indicating a continuously increasing incidence trend.[12] In the current study, we report a TBI-related mortality rate of 69.76 per 100,000 person-years with an annual increase of 1.6% in women, but no change in men or overall. In retrospect, it has been reported that during 1991–2005 the incidence rate of TBI-related death decreased in males, but not in females when a corresponding age group was studied.[12] In many other high-income countries, both TBI-related hospitalisation and mortality rates have been on the rise among the older people.[13,14,15,16,17] This may partially be attributed to the recommendations of routine use of head computed tomography by present guidelines for patients with acute TBI in their older adulthood.[18,19] This might also result in diagnosing more minor and symptomless haemorrhages, which are less likely to require surgery.

The current results indicate that the incidence rate of TBI-related hospitalisations increased in both genders, whereas the increase is more drastic in women. At the same time, the overall TBI-related mortality remained stable and IHM decreased in men, while in women, the overall TBI-related mortality increased and IHM remained stable. Moreover, men who are hospitalized due to TBI are less likely subjected to surgery. American results also show that the incidence rate of hospitalisations due to TBI among the older people is on the increase, especially among older women.[20]

We observed an annual decrease of 1.1% in the rate of ANOs among older people who were hospitalized due to TBI despite of the increasing incidence rate of hospitalisations during 2004–2014. Most of the ANOs were performed on males and the most common ANO was evacuation of chronic subdural hematoma via a burr hole. This finding is in compliance with earlier reports indicating that the incidence rate of chronic subdural hematomas is significantly higher in the geriatric population[21,22,23] and there is a trend towards increased incidence due to increase in life expectancy[24,25]. In the current study, the percentage of mini-invasive ANOs was 74% among patients <80 years of age and 89% among patients ≥80 years of age.

We investigated both IHM and overall mortality due to TBI, because in terms of geriatric TBI, short-and long-term mortality differ from that of younger counterparts. In case of severe geriatric TBI, high short-term mortality of 57–80% has earlier been reported[8,26,27,28], while reports on long-term mortality are scarce. A Dutch study reported rate of IHM of 28%[29] and a Greek study rate of IHM of 47%[30] among older adults. In the current study, we report a significantly lower rate of IHM of 7.9%. Because mortality is related to age, comparisons of the results are difficult to make due to variability in the reporting of the mean ages. The figure from the current study is somewhat similar to that

reported between 1991 and 2005 in Finland (5.1%)[12], but it should be also noted that this study investigated all age groups causing the results not to be directly comparable. We observed no change in the overall IHM. This finding echoes the observation that during the study period, there was no change in the overall mortality due to TBI. During the study years, a LOS of 7.1 days with an annual decrease of 2.5% was observed, which remained significant after adjusting with age, gender and a possible ANO during the hospitalisation episode. As the rate of geriatric TBI-related admissions is increasing, the rate of ANOs among hospitalized is concurrently decreasing along with a decline in LOS, there may be an ongoing paradigm shift in the management of TBI in older adulthood. More specifically, this may mean more accurate patient selection for surgery and more rigorous monitoring of the patients.

The strengths of the study are the population-based design and the robust Finnish obligatory databases. There is a paucity in the TBI literature concerning the changing epidemiology of geriatric TBI and its impact on the rate of ANOs performed to these individuals. In this study, TBI-related hospital transfers were combined as one hospitalisation, which underlines the reliability of IHM rates and LOS. Nonetheless, there are methodological limitations in this study that require acknowledgement. Due to the retrospective and administrative nature of the data, there is some uncertainty. We were unable to study different severities of TBI individually, because the data search was based on the ICD-10 coding. Inclusion of chronic subdural hematomas in the TBI category can be considered somewhat controversial as the lesions do not necessarily represent acute TBI. However, inclusion may be justified by the fact that patients have (i) received a diagnosis of a TBI, (ii) been hospitalized after a diagnosis of a TBI, and (iii) in many cases, undergone acute surgery during a hospitalisation period due to a symptomatic hematoma. Furthermore, due to the limitations of the administrative data, we were unable to assess the trends of quality of life, frailty, or functional outcome following TBI over time.

Conclusions

The main finding of the study is that occurrence of TBI drastically increases with aging. The overall results including both genders show that (i) the incidence of geriatric TBI-related hospitalisations increased, but the overall LOS and the rate of ANOs among hospitalized decreased in Finland and (ii) despite of significantly increasing age of patients with TBI, the rate of IHM and TBI-related mortality remained stable.

The gender-specific result show that (iii) while the rise the incidence rate of TBI-related hospitalisations is more pronounced in women, and (iv) TBI-related mortality remained stable and IHM decreased in men, while in women, TBI-related mortality increased and IHM remained stable, and (v) men who are hospitalised due to TBI are less likely to undergo surgery due to their TBI. The findings suggest that TBIs in older women are drastically on the rise and seem to have more severe consequences than in men. The risk of TBI in older women should be given more attention on the societal level. However, the overall incidence rates of TBI-related hospitalisations and deaths, and the number of cases of IHM are still higher in men. The current results merit further studies concerning geriatric TBI severity and long-term outcome.

Statements

Ethical approval and informed consent

This is a retrospective registry study and no approval from an ethical committee was required.

Data availability statement

Due to national data protection legislation, the register data used in this study cannot be shared without applying for permission to use the data with a specific study protocol and scientifically justified study questions.

Declaration of Conflicts of Interest

None.

Declaration of Funding

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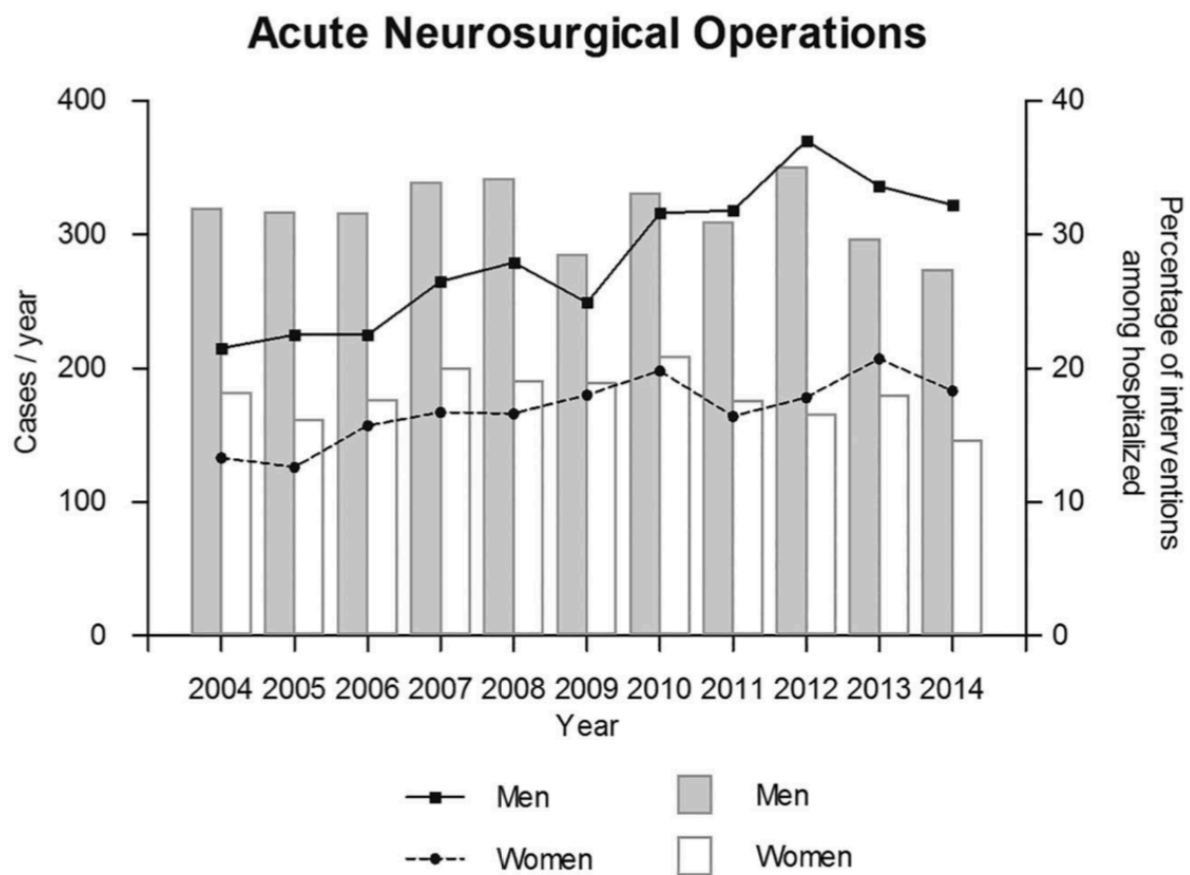


Figure 1. Rate of neurosurgical interventions due to traumatic brain injury in patients ≥ 70 years of age. The lines represent number of cases per year (left Y-axis) and bars represent the percentage of neurosurgical interventions among the hospitalised patients (right Y-axis, zoomed).

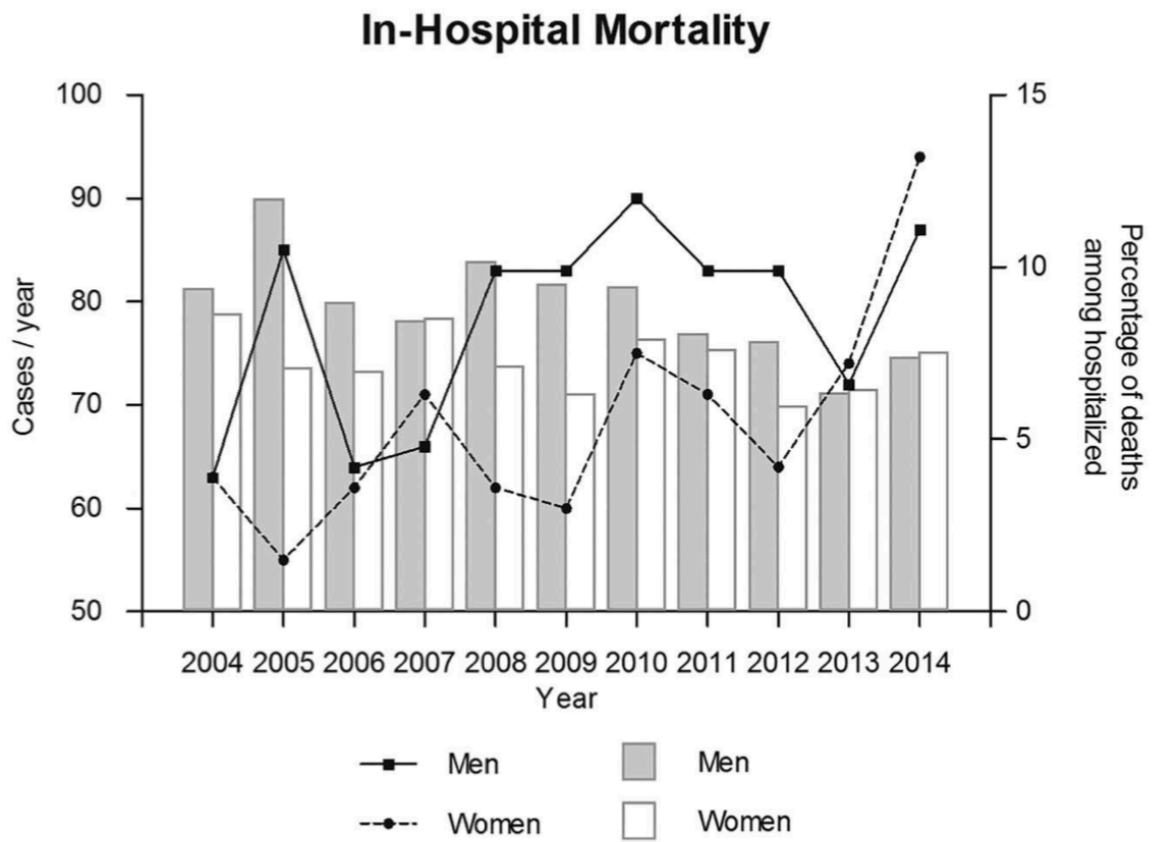


Figure 2. Rate of in-hospital mortality related to traumatic brain injury in patients ≥ 70 years of age. The lines represent number of cases per year (left Y-axis) and bars represent the percentage of in-hospital mortality among the hospitalised patients (right Y-axis, zoomed).

Table 1A. Incidence rate of traumatic brain injury-related hospital admissions in the Finnish population aged ≥ 70 years during 2004-2014; *per 100,000 person-years

Age (years)	Men		Women		Total	
	n	Incidence rate*	n	Incidence rate*	n	Incidence rate*
70-74	2576	234.44	1597	118.95	4173	170.93
75-79	2806	337.77	2200	185.22	5006	247.99
80-84	2394	453.35	2791	289.06	5185	347.14
85-89	1485	629.42	2383	404.57	3868	468.89
90-94	525	777.92	1142	486.79	1667	551.83
95-99	93	832.44	232	447.39	325	515.64
100-	14	1688.8	21	399.32	35	574.90
Total Crude	9893	356.74	10366	236.85	20259	283.34

Table 1B. Incidence rate of traumatic brain injury-related deaths in the Finnish population aged ≥ 70 years during 2004-2014; *per 100,000 person-years

Age (years)	Men		Women		Total	
	n	Incidence rate*	n	Incidence rate*	n	Incidence rate*
70-74	558	50.78	232	17.28	790	32.36
75-79	643	77.39	371	31.24	1014	50.23
80-84	662	125.36	582	60.28	1244	83.29
85-89	531	225.07	629	106.79	1160	140.62
90-94	205	303.76	396	168.80	601	198.95
95-99	61	546.01	101	194.77	162	257.03
100-	6	723.76	11	209.17	17	279.24
Total Crude	2666	96.14	2322	53.05	4988	69.76

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