Spatial-temporal analysis of head injuries at the northwest of Iran 2014–2018

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Research Article

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Abstract

Background: head injuries (HI) are considered as a major public health concern across the world. This study aims to explore the incidence rate and spatial distribution of HI incidence at rural district levels in Zanjan province, Iran from 2014-2018.

Materials & Methods: This study was a cross-sectional and geospatial analysis of head injury incidence pattern in rural areas at Zanjan province, Iran. Data were collected from nine hospital information system databases. Age-adjusted incidence rate and three different spatial analysis methods (Spatial autocorrelation, hotspot analysis and Anselin Local Moran's I) were used to detect the potential high-risk areas of HI incidence in the study area.

Results: 4562 patients were registered at Zanjan hospitals due to HI from 2014-2018. The age-adjusted incidence rate of HI was 429 cases (95% CI, 418,443) per 100,000 person which increased from 74 cases in 2014 to 86 cases in 2018, (an 18% increase, P<0001). The highest incidence rate observed among men (80%, P<0001) and at the age group of 15-29 (44.4%, P<0001). Qarabolagh region had the highest incidence rate and five hotspot, seven coldspot, two high-high cluster and seven low-low cluster of HI incidence were detected using spatial analysis.

Conclusion: This study provided an overview about the incidence rate and spatial pattern of HI incidence at finer geographical level at the northwest of Iran. This study detected high-risk areas and also showed a significant relationship between HI, geographical areas and genders, which can provide useful information for local health authorities to apply prevention programs for reducing the burden of HI in the society.

Introduction

Head Injuries (HI) are one of the most common and prominent external cause of mortality and morbidity among young people in the world.(1, 2) HI may result in functional and aesthetical impairments. Patients with HI may experience different concurrent injuries, some of which are life-threatening, such as concussions.(3) In addition, to the possible life-threatening nature of HI that occurs accompanied by other organ damages, such as fracture of nasal or skull, brain injuries, or eye tears, they might cause esthetic or functional deformities which lead to psychological, financial and social costs for community.(4) According to the Global Burden of Disease Study in 2016,(5) 27.08 million new cases of traumatic brain injury were detected in 2016, with age-adjusted incidence rates of 369 cases per 100,000 population-year. Mortality rate of HI was 21% in the first month in developed countries, while it was 50% in developing countries.(6) Interpersonal violence in developed countries and road traffic accidents in developing countries were reported as the main cause of HI.(7)

Epidemiology of HI can be varied according to population, cultural and geographical risk factors.(8) Low and middle-income countries were defined as the high risk areas of HI incidence. Road traffic accidents, falls from heights, dangerous activities, and interpersonal violence were reported as the most common causes of HI incidence at these areas.(7) The increased trend of HI among young-aged people, has made it as a major public health concern in the world, although most of these injuries can be easily prevented by

taking affective precautions.(9) Spatial-temporal analysis can play an important role in detecting the potential high risk areas of HI and generate new knowledge for policymakers for adopting better prevention strategies to reduce HI incidence rate.(10) In addition, HI can be resulted in long term disability, providing comprehensive information on geographic patterns can inform resource allocation for post-injury care, including rehabilitation. Spatial analysis tools such as global Anselin Moran, hotspot analysis and cluster and outlier analysis has been used in the number of studies to investigate the spatial distribution of diseases.(11, 12) However, there is limited research on the geographical analysis of HI in Iran and this is a significant gap. Therefore, it highlights the need to explore the etiology, epidemiology and spatial distribution of HI to detect the potential high-risk areas and groups for adopting better prevention strategies.(1, 3, 10) This study aims to explore the incidence rate and spatial-temporal analysis of HI at district levels in rural areas at the northwest of Iran from 2014-2018.

Method

We used a cross-sectional design and conducted a spatial variation of head injury in Zanjan province, Iran. Zanjan province is located at the northwest of Iran with 291.27 square kilometers area and a population of 1,057,461 people in 2016.(13) (Fig 1). Data gathered from nine hospital information system (HIS) databases and include sex, discharge diagnosis code, residential address, date of admission, and date of discharge which were registered in hospitals’ HIS over a five-year period between March 21, 2014 and March 21, 2019. According to the International Classification of Diseases 10th revision, patients who discharged with a diagnosis code between S02.0 and S02.9 (fracture of skull and facial bones) were selected as HI patients in this study. Latitude and longitude coordinates of each patients’ residential addresses were obtained using google MyMap. These data were then exported to ArcGIS 10.7 software (ESRI Inc., Redlands, CA, USA) for geo-statistics analyses. The population of each area was obtained from the national population census in 2016. (Fig 4-A) Crude incidence rate and age-adjusted incidence rate were calculated for each rural district per 100,000 person. A direct standardization approach was used to calculate the age adjusted incidence rate of HI (AAIRHI)(14). The entire population of Iran and the entire population of Zanjan province were used as the standard population to calculate AAIRHI for each rural areas. Statistically significant tests were at 95% confidence interval (CI). All statistical analysis were performed in R studio software (15). Spatial analysis methods including spatial autocorrelation (Global Moran's I), hotspot analysis, cluster and outlier analysis (Anselin Local Moran's I) were used to explore the spatial pattern of HI in the study area. We obtained ethics approval from The Ethics Committee of Zanjan University of Medical Sciences (ZUMS), Code: IR.ZUMS.REC.1398.440.

Results

Out of the total number of 42,595 hospitalized patients due to trauma during 2014-2018, 4562 (10.7%) cases were HI patients. AAIRHI was 429 cases (95% CI, 418,443) per 100,000 person, which was higher in men (80%) compared to women (20%) (671 cases (95% CI, 644,694) vs. 182 cases (95% CI, 170,194)). (Fig 2-B) The mean age of patients was 28.5±17.3 years, which was higher in women compared to men

(29.4±19.4 years vs. 27.7±15.3 years). The mean Length of Stay (LOS) was 111.3±239.8 hours which was higher in men than in women (126 ± 265.8 hour vs 96.6±213.8 hour).

The incidence rate of HI was varied among different age groups (P<0.001). The highest incidence rate was observed in the age group of 15-29 years with a significant differences compared to other age groups (752 cases (95% CI, 720,786) per 100,000 person). The lowest mean LOS was observed in the age group of 0-4 years (79.3±131.4 hours), while the age group of 70-79 years had the highest mean LOS (221.1±528.9 hours). The incidence rate of HI was higher among men compared to women in all age groups and the ratio of man to women HI incidence rate was observed in the age group of 15-29 (8.7:1.3). (Table 1)

Table 1- The incidence rate of HI in different age groups in Zanjan province

Age group	Population N (%)	Total N (%)	Men N (%)	Women N (%)	Incidence rate Per 100,000 (95% CI)	Age Mean±SD	LOS Mean±SD
0-4	96655 (9)	242 (5.3)	152 (62.8)	90 (37.2)	250 (220,284)	2.4±1.4	79.3±131.4
05-14	156269 (14.6)	552 (12.1)	397 (71.9)	155 (28.1)	353 (324,384)	9.6±3.1	95.9±227.5
15-29	269071 (25.2)	2024 (44.4)	1756 (86.7)	268 (13.2)	752 (720,786)	22.1±4.1	106.7±206.5
30-44	279653 (26.1)	1035 (22.7)	795 (76.8)	240 (23.2)	370 (348,393)	35.6±4.2	131.9±255.2
45-59	152362 (14.2)	464 (10.2)	342 (73.7)	122 (26.2)	305 (277,334)	50.8±4.2	178±419.3
60-69	55222 (5.2)	143 (3.1)	96 (67.1)	47 (32.9)	259 (218,305)	63.7±2.6	139.4±214
70-79	31428 (2.9)	74 (1.6)	50 (67.6)	24 (32.4)	235 (185,296)	73.8±2.6	221.1±528.9
+80	16801 (1.6)	28 (0.6)	18 (64.2)	10 (35.7)	167 (111,241)	83.3±4.2	119.5±165.7

N: Number, CI: confidence interval, SD: standard deviation, LOS: length of Stay

An increased trend of AAIRHI was observed in the study area from 2014-2018, which rose from 74 cases (95% CI, 69,80) in 2014 to 86 cases (95% CI, 80,92) in 2018 (an 18% increase, P<0.001). The highest incidence rate (22.3%) and the highest AAIRHI were observed in 2017 (95 cases (95% CI, 90,101) per 100,000 person). The mean LOS was increased from 101.3±196.4 hours in 2014 to 141.5±263.8 hours in 2018, a 40% increase. The incidence of HI was higher in men compared to women in all years with a ratio of ~ 8:2. (Table 2)

Table 2- HI incidence rate by years in Zanjan province from 2014-2018

Year	Population N (%)	Total N (%)	Men N (%)	Women N (%)	Incidence rate Per 100,000 (95% CI)	AAIRHI Per 100,000 (95% CI)	Age Mean±SD	LOS Mean±SD
2014	1039350	780 (17.1)	604 (77.4)	176 (22.6)	75 (70,81)	74 (69,80)	27.1±16.2	101.3±196.4
2015	1048366	913 (20.)	724 (79.3)	189 (20.7)	87 (82,93)	85 (80,91)	27.3±15.9	109.3±202.5
2016	1057461	917 (20.1)	753 (82.1)	164 (17.9)	87 (81,93)	87 (81,93)	28±16.3	130.9±362.4
2017	1066555	1018 (22.3)	813 (79.9)	205 (20.1)	95 (90,101)	95 (90,101)	28.8±16.2	113.7±211.1
2018	1075727	934 (20.5)	712 (76.2)	222 (23.8)	87 (81,93)	86 (80,92)	28.8±16.7	141.5±263.8
Mean	1057492	912.4	721.2 (79)	191.2 (21)	86.2 (81,93)	85 (80,91)	28±16.2	119.3±247.2

N: Number, CI: confidence interval, SD: standard deviation, AAIRHI: Age-adjusted incidence rate of head injuries, LOS: length of Stay

Out of the total number of 4,562 registered patients due to HI, nasal bones fractures had the highest incidence rate with 212 cases (95% CI, 203,221) per 100,000 person. The ratio of men to women was approximately 8:2 in all fractures types due to HI. Fracture of tooth was common in younger ages in the cohort (24.4 ± 15.3 years) and the highest mean LOS was observed in the fracture of base of skull (213.5 ± 323 hours). (Table 3)

Table 3- The incidence rate of fractures due to HI in Zanjan province

ICD 10 Code	Fracture of Skull and Facial bones subdivisions	Total N (%)	Men N (%)	Women N (%)	Incidence rate Per 100,000 (95% CI)	Age Mean±SD	LOS Mean±SD
S02.0	Vault of skull	307 (7)	250 (81)	57 (19)	29 (26,32)	25.4±18.9	219.1±374.1
S02.1	base of skull	378 (8)	306 (81)	72 (19)	36 (32,40)	26.9±19.4	214.5±323
S02.2	nasal bones	2242 (49)	1724 (77)	518 (23)	212 (203,221)	26.5±14.3	60.3±168.8
S02.3	orbital floor	110 (2)	90 (82)	20 (18)	10 (9,13)	31±14.4	200.8±235.6
S02.4	malar and maxillary bones	697 (15)	570 (82)	127 (18)	66 (61,71)	34±16.6	157±268
S02.5	tooth	126 (3)	100 (79)	26 (21)	12 (10,14)	24.4±15.3	121.1±306.6
S02.6	mandible	348 (8)	286 (82)	62 (18)	33 (30,37)	28.9±16.3	172.2±373.1
S02.7	Multiple skull and facial bones	17 (1)	16 (94)	1 (6)	2 (1,3)	34.7±18.1	142.7±141.2
S02.8	other skull and facial bones	197 (4)	154 (78)	43 (22)	19 (16,21)	31.3±16.4	163.2±212.6
S02.9	part unspecified	140 (3)	110 (79)	30 (21)	13 (11,16)	25.9±21.6	157.6±269.2
Total		4562 (100)	3606 (80)	956 (20)	431 (419,444)	28.55±17.35	111.3±239.8

N: Number, CI: confidence interval, SD: standard deviation, LOS: length of Stay

As figure 2 reveals, an increasing trend was observed in the incidence rate of fracture of Vault of skull, which increased from 4 cases in 2014 to 7 cases in 2018 per 100000 person-year, a 75% increase. The incidence rate of fracture of nasal bone increased from 38 cases in 2014 to 41 cases in 2018 per 100000 person-year. (Fig 2-A) The age group of 15-29 years was identified as the highest risk group for the incidence of malar and maxillary bones (108.1), mandible (60.2), nasal bones (419.2), orbital floor (20.1), other skull and facial bones (27.1) and tooth fractures (20.4) compared to other age group, while the highest incidence rates of basal skull (55.9) and part unspecified fractures (29) were in the age group of 0-4 years, the highest incidence rates of Multiple skull and facial bones fractures (3.2) were in the age group of 70-79 years and the highest incidence rate of Vault of skull fracture (53.8 cases per 100,000 person) was in the age group of 60-69 years. (Fig 2-B) An increasing trend of mean LOS was observed in the fracture of

tooth, which increased from 77 hours in 2014 to 262 hours in 2018, while the mean LOS of Multiple skull and facial bones fractures was decreased from 546 hours in 2014 to 88 hours in 2018. (Fig 2-C)

Spatial analysis results

According to the graphical and numerical outputs of Global Moran' I statistic and given the P-value of 0.003004, the spatial distribution of overall AAIRHI appeared to be significantly different than random at rural district levels in Zanjan province with a 95% CI. The spatial distribution of AAIRHI can be regarded to be clustered among men in the study area, while it had random pattern among women (P=0.006473 and P=0.376282, respectively). (Fig 3)

The incidence rate of HI was not homogenous across rural areas in Zanjan province (P<0.001). (Fig 4-B) Spatial analysis showed that Qarebolagh (the east) and Qeshlaqat (the southwest) had the highest AAIRHI compared to other areas (1026 cases and 885 cases per 1,000,000 person, respectively). Among men, the highest AAIRHI was observed in Qarebolagh and Qeshlaqat (1705 and 1639 cases per 100,000 man, respectively), which was similar to the spatial distribution of overall AAIRHI. Among women, the highest AAIRHI was observed in Soltanieh, GezelGechilo respectively (374, 332 cases per 100,000 woman, respectively), which was different compared to the spatial distribution of AAIRHI among men. (Fig 4-C)

Hotspot analysis detected one hotspot with a 99% CI, two hotspots with a 95% CI and two hotspots with a 90% CI located in the east and the center. Six cold spots with a 99% CI and one coldspot with a 95% CI were determined in the southeast. (Fig 4-D) Anselin local Moran's analysis identified seven Low-Low (LL) clusters in the southeast and two High-High (HH) cluster in the center of the study area, which was consistent to the results of hotspot analysis. Gilvan region was determined as a High-Low (HL) outlier, an area with high AAIRHI, which surrounded by regions with low AAIRHI. The hotspot patterns of AAIRHI was different among men compared to women. Six hotspot and eight coldspot were detected among men, while there were two hotspot and two coldspot among women. GezelGechilo was identified as a HL outlier among women in the study area, an area with high AAIRHI compared to its neighbors. (Fig 4-E)

The incidence of HI varied across the years and an ascending trend was observed in the study area from 2014-2018 (P<0001). (Fig 5-A) AAIRHI was increased approximately doubled at Bonab during a five-year period which known as the first populated region (from 52 cases in 2014 to 99 cases in 2018 per 100,000 person), while the highest increase of AAIRHI was occurred at Darasjin which increased from 0 case in 2014 to 142 cases in 2018 per 100,000 person. A significant increase in AAIRHI was also observed at QezeGechio which increased from 0 to 103. While AAIRHI was increased in most regions, a significant descending trend was detected at SaeedAbad which decreased from 57 cases in 2014 to 0 cases in 2018 per 100,000 person. (Fig 5-B)

Spatial autocorrelation analysis showed that the Moran's I statistic was significant (Moran's Index: 0.241111), and the spatial pattern of AAIRHI was clustered in the study area. As figure 5 reveals, three hotspots with a 99% CI were identified at the north of the study area in 2014 which was not detected again during 2015-2018. The southeast of the area was determined as a coldspot across all years. The number of hotspots was decreased from 5 in 2014 to 0 in 2018. The spatial pattern of hotspots was changed from

2014-2018 and shifted from the north to the center. (Fig 5-C) Anselin local Moran's I analysis showed that different spatial clusters of AAIRHI was detected among various years during 2014-2018. The number of clusters was decreased from 2 HH cluster in 2014 to 0 cluster in 2018. One HL outlier was detected at Golabar, an area with high AAIRHI that surrounding by areas with low AAIRHI. (Fig 5-D)

The incidence of HI was not same among men across different years and an ascending trend was observed during 2014-2018 (P <0001). (Fig 6-A) It was increased from 114 cases in 2014 to 129 cases in 2018 per 100,000 man, a 14% increase. Among men, the highest AAIRHI was observed at QareBolaq with 1705 cases per 100,000 man. The highest increase of AAIRHI was detected at Khoramdareh which increased from 14 case in 2014 to 109 cases in 2018 per 100,000 man, while the highest decrease was observed at Qeshalaqat which decreased from 251 cases in 2014 to 0 case in 2018. A significant increase of AAIRHI also observed among men at Daram (form 87 to 542 cases), ChaiparehBala (from 50 to 297 cases) from 2014-2018. (Fig 6-B)

Spatial autocorrelation analysis showed that the Moran's I statistic was significant among men (Moran's Index: 0.219330), and the spatial pattern of AAIRHI was clustered among men in the study area. As figure 6 reveals, the spatial distribution of hotspots and coldspots was changed among men over a five years in Zanjan, which shifted south from center. Among men, three hotspot were recognized in the study area in 2018, which were different from those observed previously. The number of hotspots and coldspots was decreased from five hotspot and four coldspot in 2014 to three hotspot and three coldspot in 2018. (Fig 6-C) Anselin local Moran's I analysis showed that the spatial clusters of AAIRHI was different among men across various years which consistent with the results of hotspots analysis. Two HL outlier and two LH outlier was observed among men in 2018 which were different from those observed previously. As figure 5 shows, different coldspots were detected at the southeast which most of them was same among various years. (Fig 6-D)

The incidence of HI was not homogenous also among women across different years and an ascending trend was observed from 2014-2018 (P<0001). (Fig 7-A) AAIRHI was increased from 34 cases in 2014 to 41 cases in 2018 per 100,000 woman, a 20% increase. Among women, Soltanieh had the highest AAIRHI with 374 cases per 100,000 woman. Darasjin had the highest increase of AAIRHI compared to other regions, which increased from 0 cases in 2014 to 349 cases in 2018 per 100,000 woman. A significant ascending trend also observed at Dolatabad (from 0 to 346), GezelGechilo (from 0 to 225) and Qeshalaqat (from 0 to 143) from 2014-2018. (Fig 7-B)

Moran's I statistic was not significant among women (Moran's Index: 0.058904), the spatial pattern of AAIRHI for women was random in the study area. As figure 7 shows, the spatial distribution of hotspots and coldspots was changed among women over a five years period which shifted from the north to the southwest. Among women, three hotspots were detected in 2018 which were different from those observed previously. (Fig 7-C) Anselin local Moran's I analysis showed that the spatial clusters of AAIRHI was different among women across various years during 2014-2018, which consistent with the results of hotspots analysis. While no HH cluster was defined in 2014, one HH cluster detected in Darasjin located at

the southeast. While AbharRoud was determined as HL outlier in 2014, it was detected as LH outlier in 2018 (Fig 7-D)

Discussion

The main aim of this study was to identify the spatial patterns of Head Injuries in rural setting at the northwest of Iran. Head injuries are the frequent cause of physical disabilities and even death due to traumas in the world. (16) According to the authors' knowledge, this is the first study examined the incidence rate and spatial pattern of fracture of skull and facial bones as the well-known complications of head injuries in Zanjan province. Due to the proximity of Zanjan province with seven other provinces (Ardabil, Gilan, Qazvin, Hamedan, Kurdistan, East and west Azerbaijan) and locating in mountainous zone which causes heavy traffic congestion and consequently increases the possibility of road accidents, the results of this study can be useful for local health authorities to design tailored intervention strategies to reduce HI incidence rate across rural areas.

The overall AAIRHI was 429 cases per 100,000 person and 85 cases per 100,000 person-year in the study area which was higher in men (80%) compared to women (20%). The mean age of patients was 28.3±17.3 years and the highest AAIRHI was observed at the age group of 15-29 years (44.4%). Previous studies showed that HI were more common among patients who were admitted at trauma centers.(17, 18) Our findings were in line with previous research which reported that HI had the highest incidence rate among men and at the age group of 20-30 years compared to other trauma in Ardabil (17), Sari (18), Urmia (19), Kashan (6), East Azerbaijan (2), Mashhad (16), Kerman (4), Hamadan (8) and Shiraz (20) provinces in Iran. While HI incidence rate was 144 cases per 100,000 person-year in Tehran, Iran (21), which was higher than the results of present study. Incidence rate of HI was reported 200 cases in developed countries (22) and 235 cases per 100,000 person in Europe. (23)

According to Beogo's study in Burkina Faso, out of 349 registered trauma patients, fracture of mandible (44.5%), the zygomatic complex (38.9%), and the maxilla (13.8%) injuries had the highest frequencies respectively.(3) More than half of (58.2%) of fractures were occurred in the age group of 20-39 years, and it was higher in men compared to women with ratio of 7.1:1 men to women, which was consistent with the results of this study.(3) Fractures of Mandible was reported as the most common consequences of HI ((3, 16, 24, 25), while it was accounted only 8% of cases in the present study. Zandi and Rezaie reported nasal bone's fractures were the most prevalent type of trauma in Iran, which consistent with our findings. (26, 27) Differences in the frequency of fractures among various studies can be related to the variations in the population, methodology of study, cultural, geographical and socio-economic factors.

The mean LOS of HI was 111.3±239.8 hours in the present study, which increased by age and was higher among men compared to women, which consistent with other studies' reports in Iran.(8, 28, 29) we did not compared the mean LOS across studies due to impact of actors such as patient's age, payment classification, specialty of doctor, type of hospital, care protocols, and hospital resources had influence on the mean LOS in hospitals.

There was a statistically significant correlation between genders and HI (P<0.001). While the men-to-women population ratio was not significantly different in Iran and the study area (13), men-to-women ratio of AAIRHI was 4:1 in the present study. HI ratio of men to women was fluctuated between 2.5 and 5 in other studies in Iran (17, 19), which consistent with the results of this study. An explanation for this is that females aren't motorcyclists in Iran and men often participate in high risk activities away from home and use derives more heavy and industrial vehicles and motorcycles compared to women and this may relate the low incidence of HI in women in Iran. (2, 30, 31) Although the majority number of HI were occurred among men across the world, it can be changed according to the cultural and socio-economic factors. For example, men to women HI incidence ratio was 2.1:1 in Austria due to a greater involvement of women in socio-economic activities outside the home (32), on the other hand, it was 11:1 in the UAE due to the cultural setting in where men usually do outdoor and few women have access to (or can drive) motorized vehicles. (33).

AAIRHI was increased 18% in Zanjan province during 2014-2018, while the population density was increased only 4%. An ascending trend of HI was also reported in the number of studies across developing countries which was consistent with the results of present study, while a descending trend was reported in developed countries which attributed to decreasing of HI's risk factors in these areas.(34) Decreasing road accidents due to traffic laws implementation and increasing the safety of motor vehicles were the main reason that influence on the descending trend of HI in developed countries. In comparison, population growth, urbanization, weak public transport system, increasing number of motorized vehicles along with increasing the traffic accidents, non-compliance of speed limits, not fasten the seat belt and falling from a height were reported as the most common cause of HI in developing countries. (7, 23, 34)

According to the Statistics Center of Iran,(13) Bonab, Hoomeh 2 and Khorramdareh regions had the highest population density in the study area in 2016. (445018, 105330 and 67260 person, respectively) Bonab region is the first metropolis and populated region in the study area which classified as the ninth high-risk area of AAIRHI with 546 cases per 100,000 person. Qarabolagh and Qeshlaqat regions defined as the first and the second high-risk areas of AAIRHI, while they had lower population density compared to other areas (6699 and 1823 person, respectively). These results showed that in addition to population density, different risk factors might influence AAIRHI such as individual characteristics (age and gender), lifestyle and work activity type, socio-economic statue, and environmental factors. However, more studies are needed to detect the main causes and risk factors of HI in these areas.

Spatial analysis include different statistical techniques that can be used to detect the potential high risk areas of diseases.(35) Hotspot analysis and Anselin Local Moran's I are advanced statistical techniques that used to determine the spatial patterns of HI in different health studies.(10, 12, 36, 37) Spatial analysis play an important role to visualize the spatial patterns and identify the high-risk areas of HI incidence. Global Moran's I analysis can identify the spatial pattern and existence of spatial autocorrelation in HI pattern. This technique determines whether HI had a random, clustered or scattered pattern, but it cannot detect where clusters are located. Hotspot and Anselin Local Moran be able to detect the potential location of clusters which were used in the present study.

The results of this study showed that AAIRHI was not distributed homogeneously across rural region in Zanjan province. The results of Global Anselin Moran's index analysis showed that the distribution of AAIRHI was spatially clustered and most of hotspots and HH clusters were observed at the vicinity of center and east, while coldspots and LL clusters were determined at the south-east of study area. According to Colantonio's Study in Canada (10) , Maia and Bernardino studies in Brazil (36, 37), Prasannakumar's study in India (12), Giang's study in Vietnam (38) also showed a different spatial pattern of HI and trauma which consistent with the results of this study. This study along with previous studies on spatial pattern of HI and trauma approved the efficiency of Anselin Local Moran and hotspot analysis methods to define area level hotspots of HI.

The highest AAIRHI was observed among rural areas that can be related to widespread use of motorbike and increased falls from height in these areas. Lifestyle, socio-economic and cultural differences, poor access to urban services and public transportation systems, frequent use of motorcycles had been reported as the common causes of HI among the people who lived in rural areas. (39) However, more data and further investigations are needed to identify the main risk factors that contribute to HI incidence in rural areas in Iran.

Health resources such as MRI, CT scan devices and availability of specialists are necessary for HI treatment in developing countries. However, these resources mostly available in larger cities, and people who are living in rural areas rarely has access to these services. Transportation in rural regions is often costly, lengthy and difficult to organize. Therefore, it's needs to be planned well and allocated health resources equitably to support patients with HI in rural area. The allocation of limited health resources should be focused on high-priority areas with the greatest risk of AAIRHI. The results of this study can enable local authorities to develop tailored intervention to areas where the risk of HI is greater.

Conclusion

Our findings showed that AAIRHI varies across rural communities in Zanjan province, Iran. Early diagnosis and interventions are crucial to prevent morbidity and mortality due to head injuries. This study highlighted high-risk areas in the pattern of HI and also showed a significant relationship between HI, geographical areas and gender, which can provide useful information for local health authorities to design prevention strategies to reduce the burden of HI in the society.

Limitation

This study had two limitations. First, we collected the information of patients who were hospitalized due to HI in hospitals affiliated to Zanjan University of Medical Sciences during 2014-2018. The data of three private hospitals did not included in this study. Therefore, it may not represent the overall HI patients in Zanjan province, Iran. Second, the population census is conducted every five years in Iran, thus, there is no annual population census, we projected population estimations for other years using the 2016 national population census data as a baseline by taken into account the growth rate of population which reported every year by Iran statistical center. Third, due to incomplete data of hospital information systems which

used in this study, we couldn't explore the reasons for head injuries across rural communities and subgroups in the study area.

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of Zanjan University of Medical Sciences protocol Number: IR.ZUMS.REC.1398.440. All methods were performed in accordance with the principles of the Declaration of Helsinki and all protocols were carried out in accordance with relevant guidelines and regulations. Data gathered from hospital information system databases and data collection for this research was approved by the Health Systems Research (HSR) committee of Zanjan University of Medical Sciences protocol Number: A-12-1171-4. Informed consent was not obtained due to the nature of the study and the gathered data did not include any identification items and the ethical committee of Zanjan University of Medical Sciences approved that with protocol number: IR.ZUMS.REC.1398.440.

Consent for Publication

Not applicable, because this study used the data of hospital information system databases which did not include any identification items.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

M.S. designed the study, drafted the manuscript and conducted the statistical analysis and was leader of the project. **M.S.**, **A.J.** and **R.G.** acquired the data from Hospitals. **N.B. and A.J.** revised the manuscript critically and adding relevant suggestions to improve the manuscript quality. All authors agreement for all aspects of the work and approval of the final version to be published.

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Availability of Data and Material

The datasets are available from the corresponding author on request.

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Figures

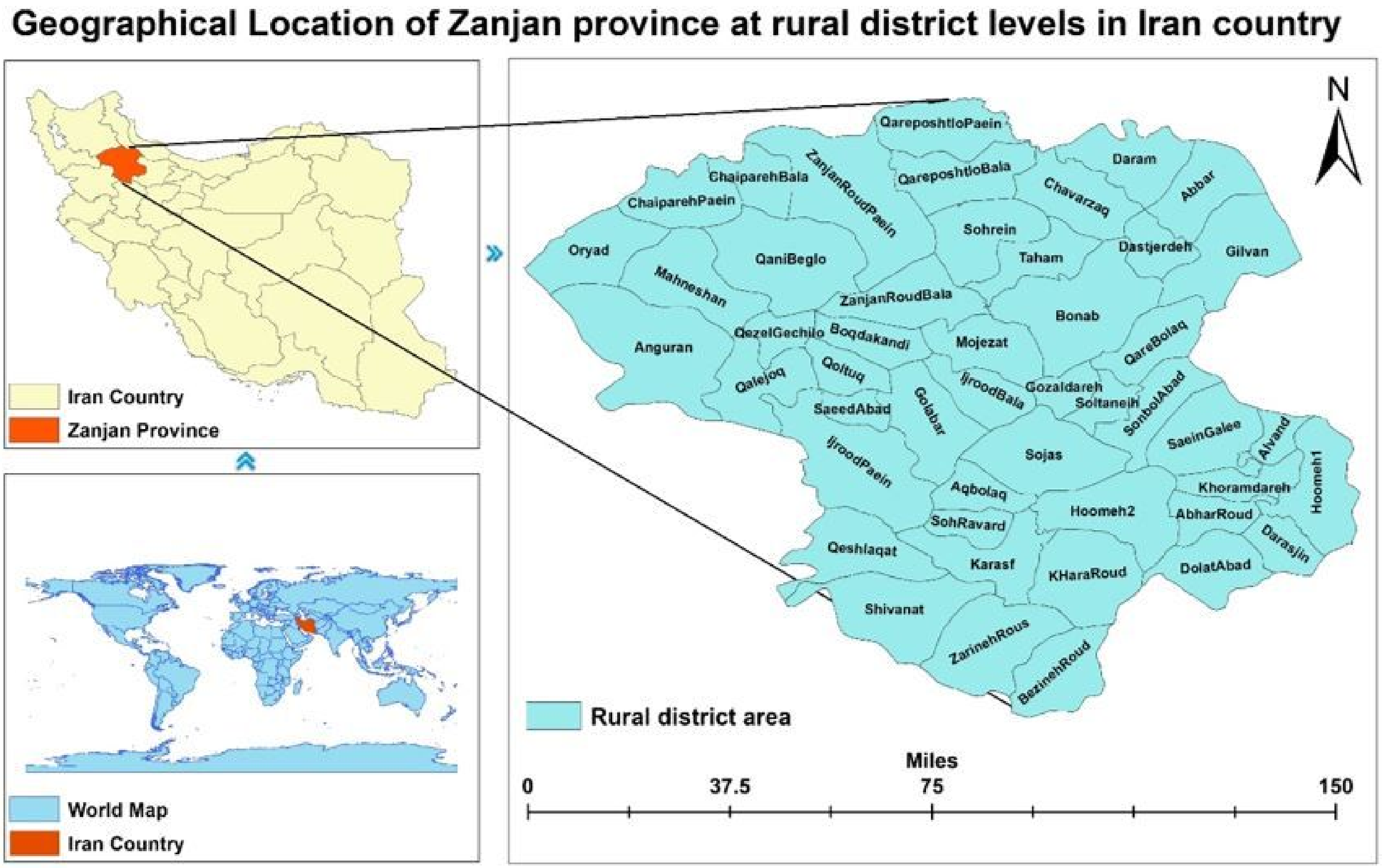

Figure 1

Geographical Location of rural areas in Zanjan province, Iran. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

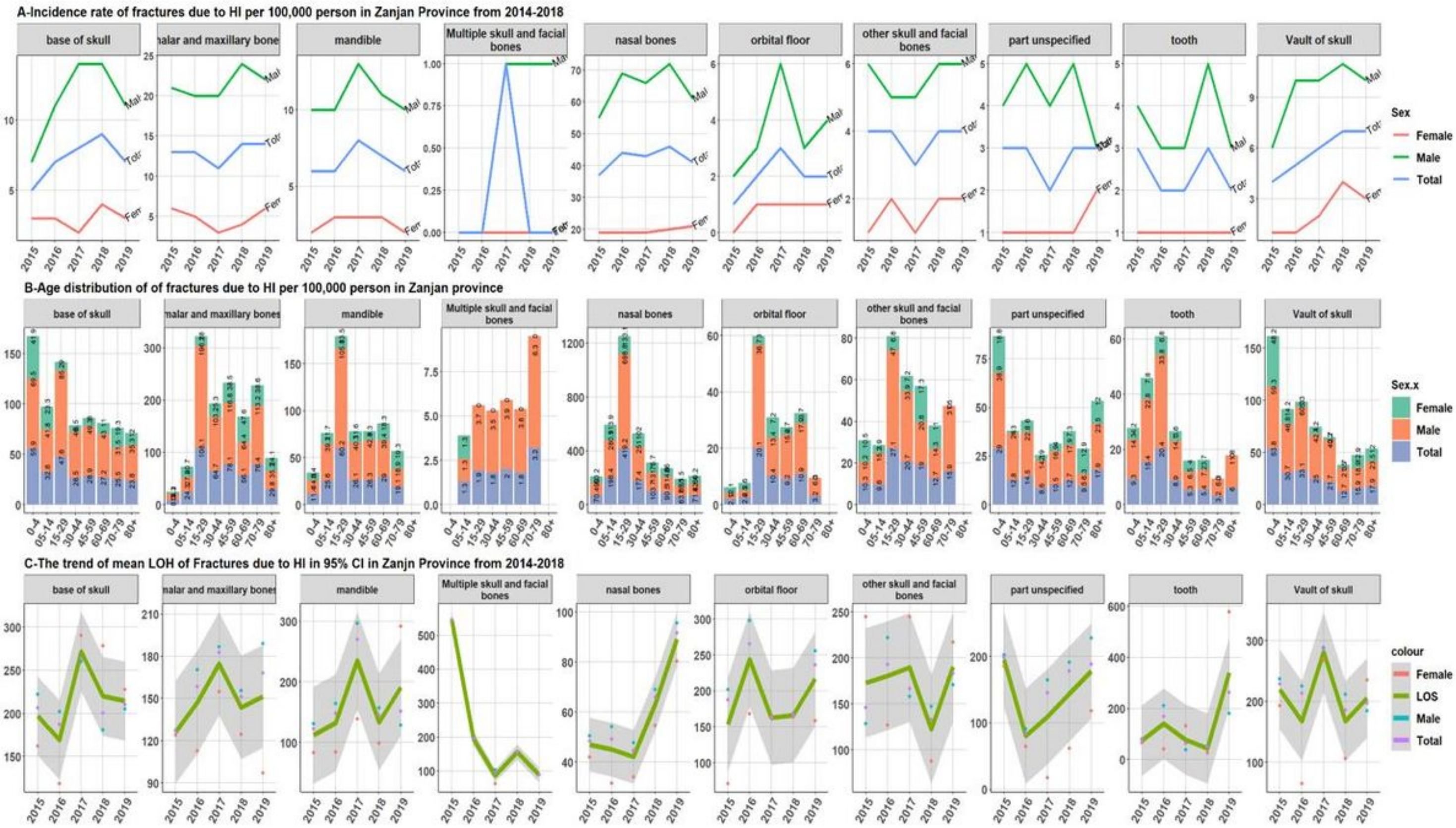

Figure 2

Incidence rate, Age-specific and mean LOS of fractures due to HI in Zanjan province from 2014-2018

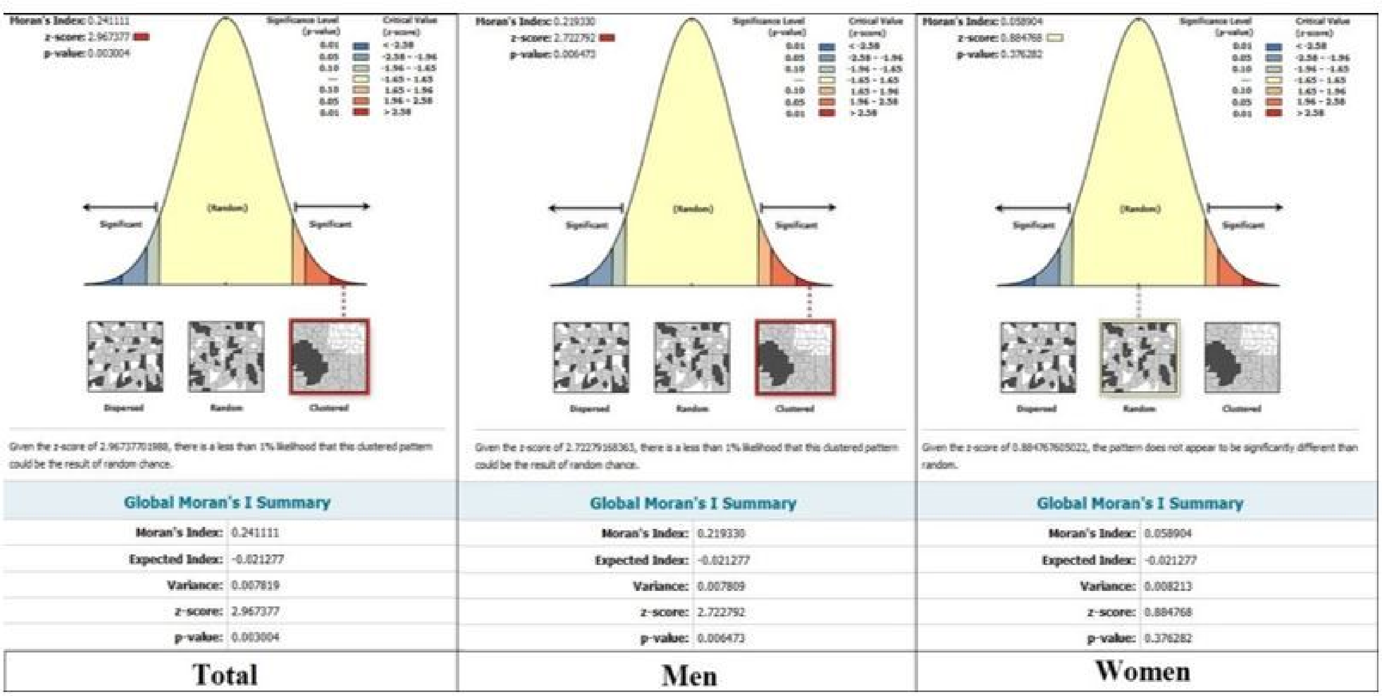

Figure 3

Graphical and Numerical outputs of spatial autocorrelation about AAIRHI in Zanjan province

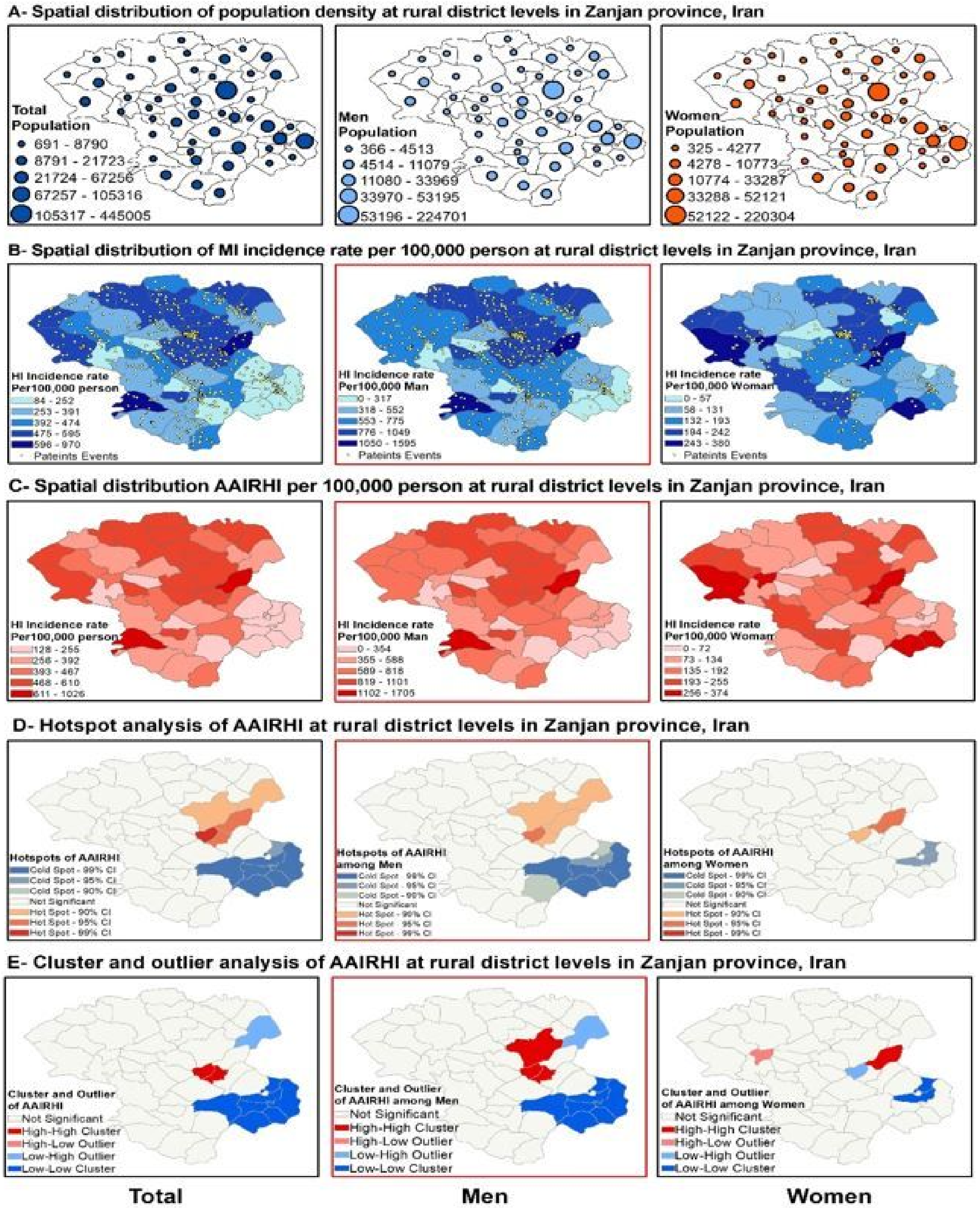

Figure 4

Spatial analysis of overall HI in Zanjan province. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

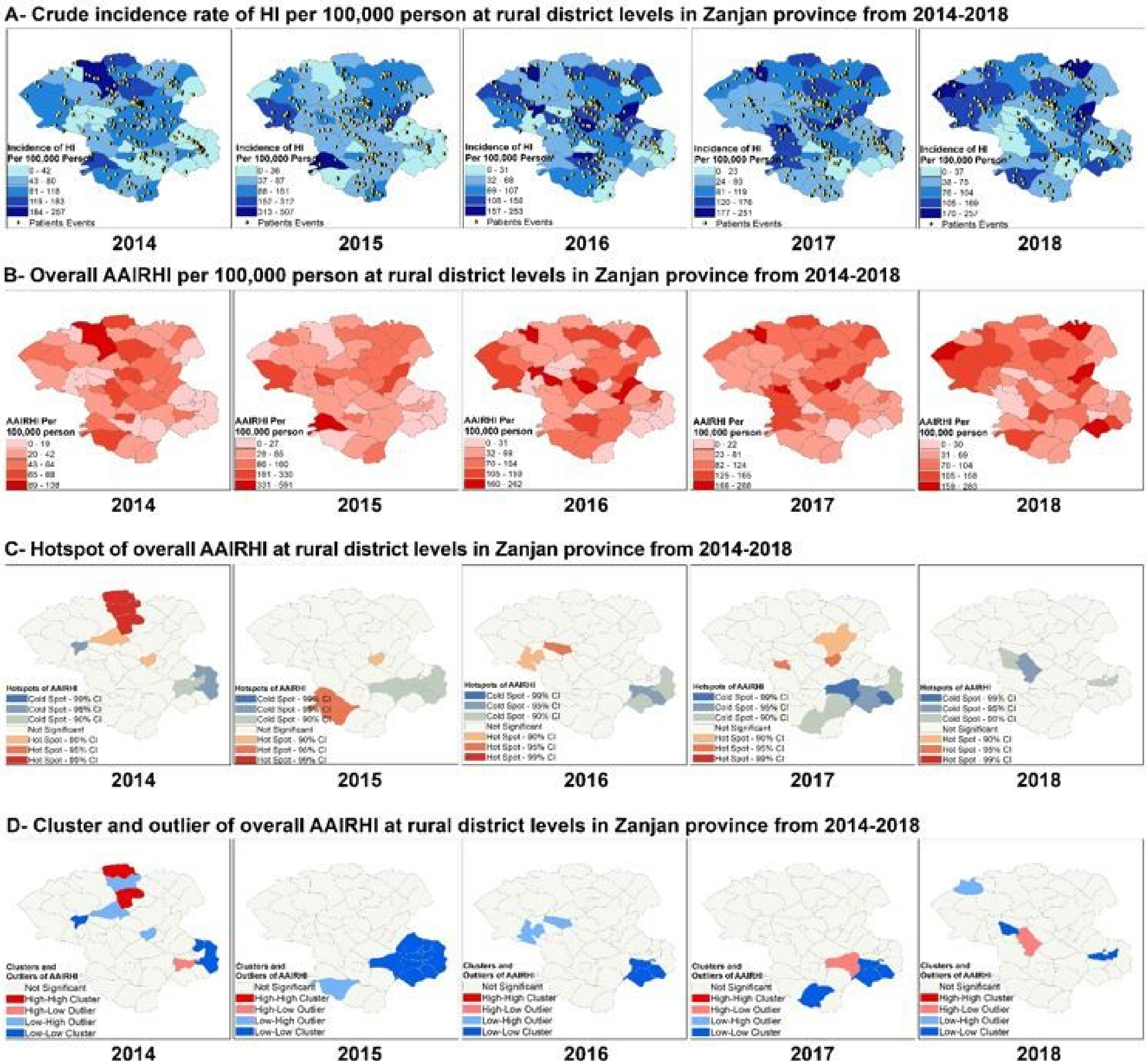

Figure 5

Spatial analysis of overall HI over time in Zanjan province from 2014-2018. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

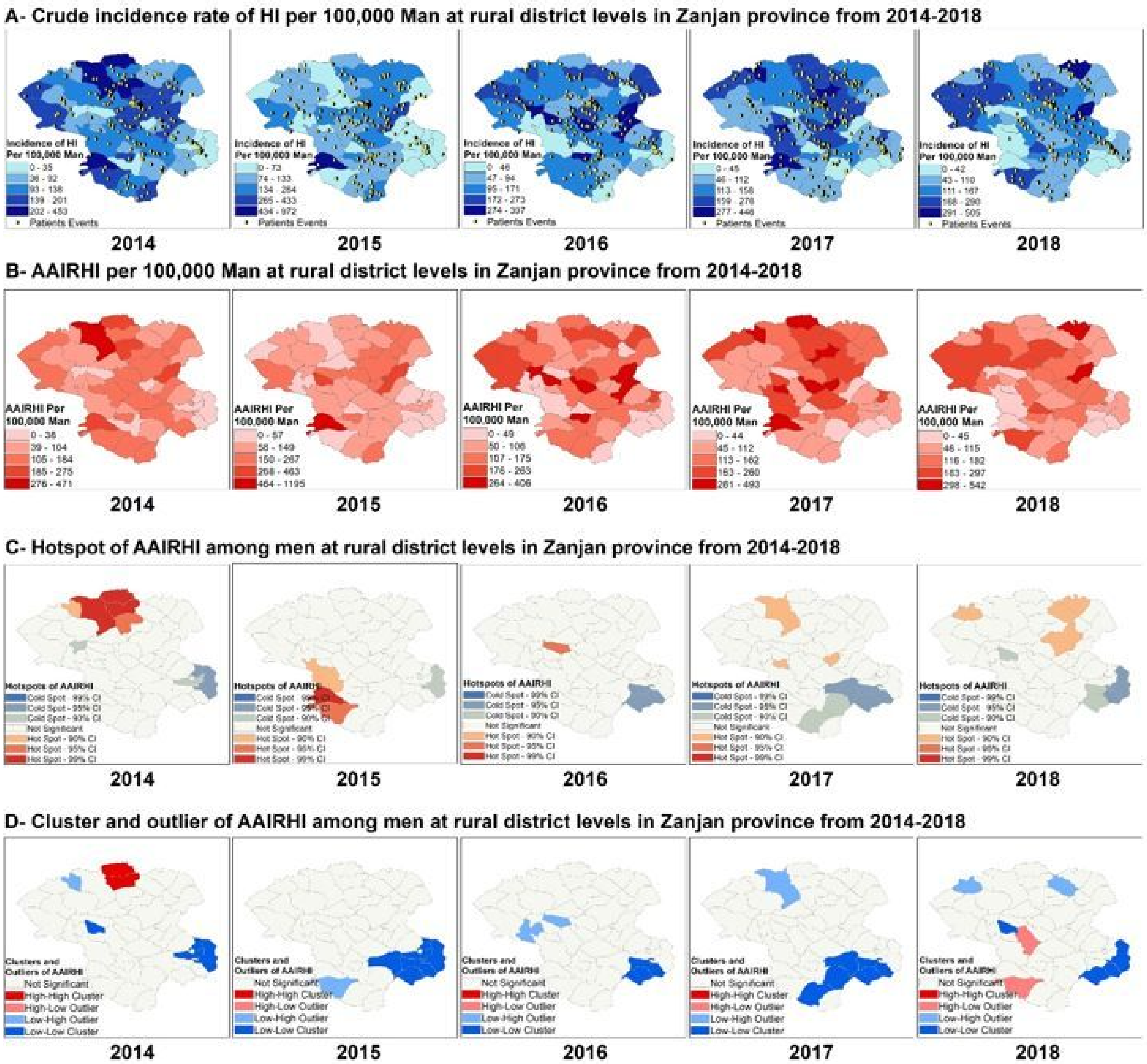

Figure 6

Spatial analysis of HI among men in Zanjan province from 2014-2018. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

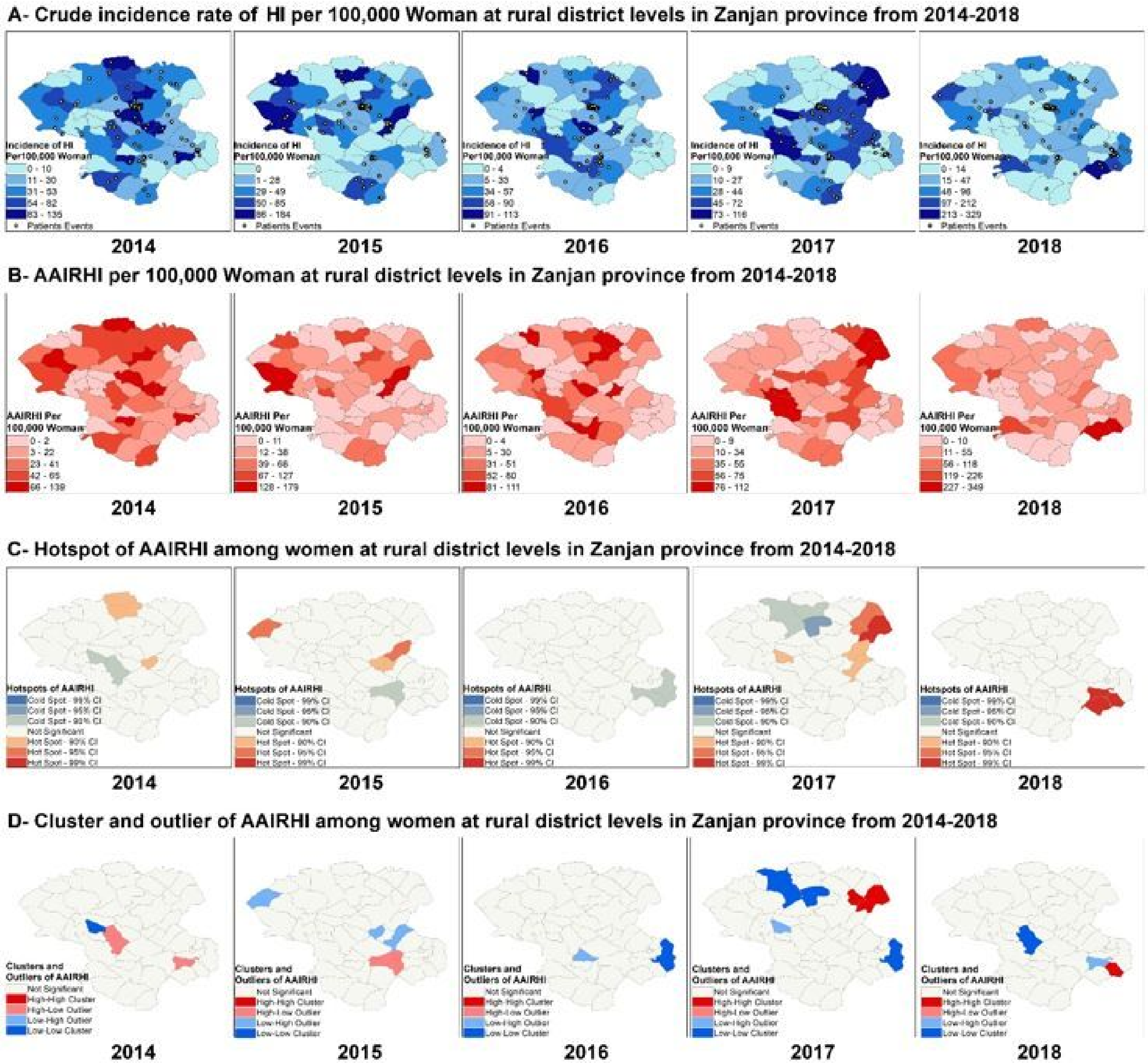

Figure 7

Spatial analysis of HI among women in Zanjan province from 2014-2018. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.