


# Seasonal impact on surgical site infections and wound healing disturbance in carpal tunnel surgery: A retrospective cohort study

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## Abstract

Carpal tunnel syndrome is the most common entrapment syndrome of a peripheral nerve. The gold standard treatment is open carpal tunnel release which has a high success rate, a low complication rate, and predictable postoperative results. However, it has not been analysed yet if there is a seasonal influence on complications for carpal tunnel release, a highly elective procedure. In this retrospective study, we determine whether there is a seasonal impact on surgical site infections (SSI) and wound healing disorders (WHD) in primary carpal tunnel syndrome surgery. Between 2014 and 2018, we have assessed 1385 patients (65% female, 35% male) at a mean age of 61.9 (SD 15.3) years, which underwent open carpal tunnel release because of primary carpal tunnel syndrome. The seasonal data such as the warm season (defined as the period from 1st of June until 15th of September), the average daily and monthly temperature, and the average relative humidity were analysed. Patient demographics were examined including body mass index, alcohol and nicotine abuse, the use of anticoagulants and antiplatelet drugs as well as comorbidities. These data were correlated regarding their influence to the rate of surgical site infections and wound healing disorders in our study collective. A postoperative SSI rate of 2.4% and a WHD rate of 7% were detected. Our data confirms the warm season, the average monthly temperature, and male sex as risk factors for increasing rates of WHDs. Serious SSIs with subsequent revision surgery could be correlated with higher age and higher relative humidity. However there is no seasonal impact on SSIs. We therefore advise considering the timing of this elective surgery with scheduling older male patients preferably during the cold season to prevent postoperative WHDs.

## KEYWORDS

carpal tunnel syndrome, seasonal impact, surgical site infection, temperature, wound healing disorder

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## 1 | INTRODUCTION

Carpal tunnel syndrome is the most common entrapment syndrome of a peripheral nerve. Spontaneous numbness in the hands is the main symptom of this neurological disease, which is characterised by sensory and motor failure symptoms. The reason for this condition is a disproportion between the space available and the space required in the carpal tunnel, resulting in a narrowing of the median nerve on its passage through this osteofibrous tunnel.<sup>1,2</sup> While there are conservative treatment options, surgical care has proven its worth because of its high efficiency and low risk of complications. Different surgical procedures have been developed with open and endoscopic surgery, but many surgeons prefer the open carpal tunnel release because it is a well-tried and tested method, has a high success rate, a low complication rate, and predictable postoperative results.<sup>3</sup> Complications of this procedure are—among others—surgical site infections (SSI) and postoperative wound healing disorders (WHD).<sup>4</sup> Some risk factors, such as obesity, diabetes mellitus, and many more, have already been investigated in previous studies.<sup>5,6</sup> However, it has not been analysed yet if there is a seasonal influence on complications for carpal tunnel release, a highly elective procedure.

Studies in several medical disciplines have already investigated seasonality and higher temperature in association with the risk of infection: many of them could prove a correlation between the SSI rate and warm summer months.<sup>7-10</sup> For example, Duscher et al investigated the seasonal influence on the infection rate after various body contouring operations. They detected a significant increase of the infection rate during the warm season and a direct correlation between higher temperatures and the postoperative risk of infection.<sup>11</sup> It seems that there is not only a seasonal influence on the rate of postoperative infections, but also on systemic infections.<sup>12,13</sup> Moreover, previous studies have also concluded that WHD can be seasonally influenced.<sup>14</sup>

It is important to determine if there is a seasonal impact on the incidence of SSI and WHD because these complications not only cause great distress for patients but also a large financial impact on the health care system. With SSI and WHD, there come large additional costs because of an extended hospital stay, additional diagnostic and therapeutic procedures, a higher risk of antibiotic resistance, and an economic damage because of the prolonged inability to work.<sup>15</sup> While carpal tunnel release complications correlate with various risk factors, the timing of the surgery is a parameter that could be optimised for patients at higher risk so that the overall frequency of these complications can be further decreased.

### Key Messages

- surgical site infections and wound healing disorders are complications of open carpal tunnel release
- in this study, we analysed seasonality and the influence of higher temperature on complication rates
- warm season, higher temperature, and male sex are risk factors for wound healing disorders in open carpal tunnel release surgery
- there is no seasonal impact on surgical site infections. However, high patient age increases the risk to suffer from a severe surgical site infection
- we therefore advise considering the timing of this elective surgery with scheduling older male patients preferably during the cold season to prevent postoperative WHDs

## 2 | METHODS

In this retrospective cohort study, all primary, open carpal tunnel release surgeries, which were carried out at our institution between 2014 and 2018, were analysed. This study was approved by the local ethics committee (#1230/2019). We evaluated whether higher temperatures have an influence on the rate of SSI and WHDs. Temperatures were assessed in detail using the average temperature on the day of the surgery as well as the average monthly temperature. We determined if the warm season, which we defined as the period from 1st of June until 15th of September, is a potential risk factor. We further assessed the average relative humidity, the body mass index, the patient age at the time of the surgery, the gender, alcohol and nicotine abuse, the use of anticoagulants and antiplatelet drugs, the operated side, and if patients are suffering from diabetes mellitus. The patient population consisted of a total of 1385 patients, resulting in 1639 cases. All patient data was collected from the hospital information system in a per-protocol analysis, that is patients, of which incomplete data were available, were not eligible to be included in the present study. Exclusion criteria were defined as surgeries for recurrent disease and post-traumatic carpal tunnel syndrome. Further, patients who had an open release of the carpal tunnel accompanied by another operation in the same surgical procedure were also excluded from the study. Based on the follow-up treatment reports, we determined whether there were SSI or WHD postoperatively. SSI were

defined using the following, clinical parameters: erythema, swelling, pain, overheating, fever, purulent exudation, laboratory values such as leukocytosis and elevated CRP-values. Moreover, the need for an initiation of antibiotic therapy and a culturally verified bacterial growth after a wound swab were indicators for SSI. Wound healing disorders were defined as all cases in which we found wound dehiscence as a result of an inadequate healing process, especially with wound secretion and macerations.

Statistical analysis was carried out via the correlation between the season and the occurrence of SSI and WHD, respectively, using the Chi-square test. Fishers' exact test was used to assess, whether the season correlates with the occurrence of infection-related revision surgery. The extent to which the average temperature on the day of surgery, the average monthly temperature, which we used to evaluate the effect of the temperature independently of daily fluctuations, and all other risk factors mentioned above affect the rate of SSI, WHD and infection-related revision surgery was evaluated using a binary logistic regression analysis. Statistical planning and execution were performed with the support of an expert for medical statistics. Local weather data such as the average air temperature on each day and the relative humidity were taken from the Central Institute for Meteorology and Geodynamics Austria.

### 3 | RESULTS

#### 3.1 | Demographics

The patient population consisted of a total of 1385 people, of which 575 were male (35%), 1067 were female (65%).

The mean age at the time of the surgery was 61.9 (SD 15.3) years, while the oldest patient was 94 and the youngest 18 years old. During the warm season the average age was 63.7 (SD 15.8) years, and during the cold season the average age was 61.28 (SD 15.2) years. The average body mass index (BMI) at the time of the surgery was 28.9 (SD 5.6), while patients in the warm season showed an average BMI of 29.2 (SD 6.2), in the cold season the mean BMI was 27.7 (SD 5.4). 35.6% of the study cohort had a BMI greater than 30.

In 55.6% of all cases (911 surgeries), the operation was performed on the right hand, in 44.4% (728 surgeries), the operation was performed on the left hand. In total, we observed alcohol abuse in 115 cases (7%). In the warm season, the rate was 5.8%, while we observed 7.4% in the cold season. In 313 (19.1%) cases, patients were smokers, during the warm season the rate was 20.5%, in the cold season 18.6%. In 363 cases (22.1%) patients took anticoagulants or antiplatelet drugs, in the warm summer months the rate was 25.4%, in the cold season there was a rate of 21% of patients who took these drugs. In total, there were 195 (11.9%) patients suffering from diabetes mellitus, in the warm season the rate was 13.8%, in the cold season 11.2%.

#### 3.2 | Season analysis

Between 2014 and 2018, the average temperature was 11.6 °C (SD 8.1). The temperature given is the average temperature all over the day measured in the city, where our institution is located. During the warm season, the average temperature was 20.9 °C (SD 3.8), the highest

**TABLE 1** Average temperature and humidity for each month over the period 2014 to 2018 with the total number of infections and wound healing disorders in the respective months

Month	Average temperature in °C	Average humidity in %	Number of infections	Number of wound healing disorders
January	1.34	76.97	2	9
February	3.45	66.72	3	6
March	7.49	54.32	5	8
April	12.29	49.19	0	11
May	16.33	54.24	3	5
June	20.24	48.33	4	15
July	21.99	48.44	4	13
August	21.67	50.55	4	7
September	16.69	59.15	2	16
October	11.85	67.58	4	12
November	6.06	74.52	6	10
December	3.03	78.20	2	3

temperature measured was 29 °C. The cold season had an average temperature of 8.3 °C (SD 6.4) and a minimum temperature of -7.8 °C. The relative humidity was measured at 2 P.M. In the warm season, there were overall 167 days (38.9% of the warm season) during our observation period, on which the relative humidity was over 50%, in the cold season there were 893 days (73.8% of the cold season) with a relative humidity over 50%. Detailed temperature and humidity values for each month as well as the total number of infections and wound healing disorders are displayed in Table 1.

### 3.3 | Complication analysis

Between 2014 and 2018, we detected 39 postoperative infections, representing an SSI rate of 2.4%. This number of infections includes every severity of this complication, that is both superficial and deep infections as well as those who

subsequently required revision surgery. We observed 20 superficial infections, resulting in a rate of 1.2% of all operations performed. There were 11 (0.7% of all procedures) deep infections and 8 (0.5%) cases which required infection-related revision surgery. During the warm season, we detected a total of 14 infections within 429 operations, corresponding an infection rate of 3.3%. Most of these infections were superficial—there were 9 superficial infections, 4 deep infections, and 1 infection with subsequent revision surgery. In the cold season, we observed 25 infections (2.1%) out of 1210 performed procedures, of which 11 were superficial, 7 were deep, and 7 required a revision surgery. In total, we found a WHD in 115 cases, corresponding a rate of 7%. There were 41 (9.6%) and 74 (6.1%) patients suffering from a wound healing disorder in the warm and in the cold season, respectively.

It could be detected that the rate of surgical site infections in the warm season (1st of June until 15th of September) compared with the cold season (3.3% vs 2.1%)

**TABLE 2** Regression analysis of the target variable infection

Covariate	P value	Confidence interval	Odds ratio
Average monthly temperature	.061	0.997-1123	1058
Average temperature on the day of the surgery	.39	0.997-1123	0.971
Average monthly humidity	.49	0.976-1052	1013
Patient age	.34	0.987-1038	1012
BMI	.80	0.932-1056	0.992
Men	.052	0.995-3836	1953
Operated side (right hand)	.41	0.681-2540	1315
Alcohol abuse	.39	0.565-4254	1551
Nicotine abuse	.77	0.339-2252	0.873
Anticoagulant/antiplatelet drugs	.45	0.306-1693	0.72
Diabetes mellitus	.43	0.183-2084	0.617

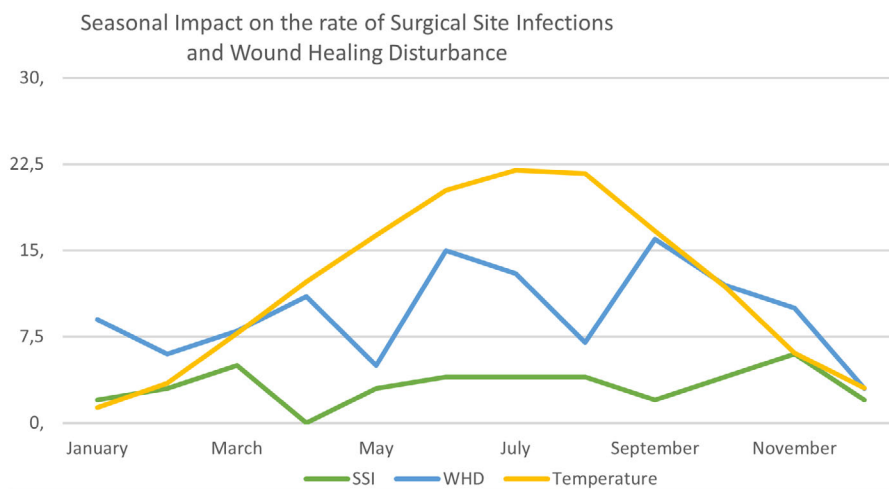
**TABLE 3** Regression analysis of the target variable infection-related revision surgery

Covariate	P value	Confidence interval	Odds ratio
Average monthly temperature	.32	0.939-1214	1067
Average temperature on the day of the surgery	.71	0.826-1139	0.97
Average monthly humidity	.038	1006-1232	1113
Patient age	.017	1017-1192	1101
BMI	.75	0.886-1181	1023
Men	.98	0.230-4515	1019
Operated side (right hand)	.53	0.367-6926	1594
Nicotine abuse	.58	0.197-17 717	1.87
Anticoagulant/antiplatelet drugs	.58	0.342-6641	1506
Diabetes mellitus	.33	0.417-12 879	2316

Note: Alcohol abuse is not included in the regression analysis because the regressor is too small.

**TABLE 4** Regression analysis of the target variable wound healing disturbance

Covariate	P value	Confidence interval	Odds ratio
Average monthly temperature	.002	1025-1116	1.07
Average temperature on the day of the surgery	.21	0.932-1016	0.973
Average monthly humidity	.41	0.987-1033	1.01
Patient age	.95	0.986-1015	1
BMI	.55	0.977-1045	1.01
Men	.041	1017-2291	1.526
Operated side (right hand)	.96	0.674-1459	0.992
Alcohol abuse	.85	0.523-2178	1.067
Nicotine abuse	.11	0.912-2409	1.482
Anticoagulant/antiplatelet drugs	.25	0.431-1246	0.733
Diabetes mellitus	.57	0.657-2141	1.186

**FIGURE 1** Number of surgical site infections (SSI) and wound healing disorders (WHD) compared with the average monthly temperature in °C

increases by 63.3%, however, no statistically significant correlation between the warm season and the rate of surgical site infections could be found ( $P = .162$ ). Even serious infections that required revision surgery occurred regardless of the season ( $P = .689$ ). However, postoperative WHDs show a correlation with the warm season ( $P = .016$ ). Compared with the cold season, the number of wound healing disorders increased by 63%, which corresponds to a relative risk of 1.56 to develop a wound healing disorder, when surgery is carried out during the warm season.

The regression analysis showed no parameter that predisposed to the occurrence of an SSI (Table 2). Risk for serious infections with subsequent revision surgery are associated with higher patient age with an odds ratio of 1.101 ( $P = .017$ ; 95% CI: 1.006-1.232). Thus, for every year the patient is older, the risk increases 1.101 times to suffer from a severe infection, which requires revision surgery (Table 3). Moreover, the relative humidity, averaged over the month, seems to have an influence as well,

because the risk increases 1.113 times with each percent humidity ( $P = .038$ ; 95% CI: 1.006-1.232). Table 4 displays the regression analysis results for the target variable WHD. As presented in Figure 1, we could determine that the average monthly temperature is directly related to the rate of postoperative WHD ( $P = .002$ ; 95% CI: 1.025-1.116; OR = 1.07). Thus, the risk to develop a postoperative wound healing disorder increases 1.07 times with every degree Celsius regarding the average monthly temperature. In men, there was a 1.526-fold increased risk of developing a wound healing disorder ( $P = .041$ ; 95% CI: 1.017-2.291).

## 4 | DISCUSSION

Our study supports the hypothesis that there is a seasonal impact on the rate of WHD in open carpal tunnel release surgery. We observed an increase of 63% in the warm season and a direct correlation between the average monthly

temperature and the rate of WHDs. Contrary to the temperature on the day of the surgery, on which most patients recover from the surgery and anaesthesia while staying in their temperature-controlled homes or in the hospital, the decisive factor concerning the healing process, however, is the temperature in the days and weeks after the operation.

The climatic conditions, that is hot temperatures and a low humidity in the summer months, lead to intensive transpiration which represents the perfect basis for growth of *Staphylococcus aureus*.<sup>16</sup> The colonisation or infection with *Staphylococcus aureus* are caused by local factors, which disrupt wound healing.<sup>17</sup> Besides transpiration, typical human behaviour during the summer, that is pursuing outdoor activities, gardening, and housework against medical advice could also be an explanation for the high number of WHD during the warm season. Another statistically significant finding was an increased risk for men to suffer from a WHD after open carpal tunnel release surgery. This study result may be explained by behaviours that are increasingly pursued by men and are harmful for wound healing. Our personal experience is, that men usually act more stubborn and are prone to take more risks. Additionally, this study result might corroborate scientific studies according to which androgens have a negative influence on wound healing.<sup>18</sup>

While there was no parameter in our study that turned out to be a risk factor for a higher rate of SSI, there were statistically significant conditions which were associated with a higher risk for infection-related revision surgery: patient age and high humidity. Thus, the present study corroborates the results published by Gruskay et al regarding the fact that humidity increases the rate of SSI. However, the study was conducted at the Thomas Jefferson University in Philadelphia, Pennsylvania, where there are usually hot summers with high humidity.<sup>19</sup> Contrary to this, the present study was performed under climate conditions involving low humidity in the summer. Because there was no increase of serious infections in the summer months and the statistical analysis showed no correlation with temperature, we were not able to detect a connection between season and infection-related revision surgery. Therefore, the role of the humidity in the context of SSI remains unclear, also because Elegbe reported higher temperatures and low humidity to be a risk factor for infections.<sup>16</sup>

The studies, in which a seasonal influence on the rate of SSI could be observed, investigated plastic and aesthetic surgery<sup>11</sup> or orthopaedic surgeries, particularly total knee and total hip arthroplasty.<sup>9,20</sup> Leekha et al performed a systematic review, in which the findings of epidemiological studies regarding seasonality are summarised. The conclusion of this review was that there is an association

between warm-weather months and *Staphylococcus aureus* skin and soft tissue infections.<sup>21</sup> These findings indicate a correlation between the season and the rate of infections. High temperatures in combination with changes in human behaviour during the summer months might be an explanation for this association. High temperature in general promote bacterial growth and increase their chance for survival.<sup>19</sup> Moreover, warm weather physiologically leads to transpiration on the patient's skin. The synergy of these two factors leads to a perfect environment for bacterial growth, particularly when it is close to surgical wounds, where bacteria are additionally provided with essential nutrients from avital detritus and wound secretion.<sup>22</sup>

Another explanation for the phenomena observed could be the so-called July-Effect. This theory, that is controversially discussed in several studies, implies that more inexperienced staff is especially in charge during the summer months because of internships, new employees, personal relocations etc., which leads to a higher complication rate, for example via extended operation time or inadequate sterility.<sup>8,19</sup> As a result of internships, the number of people in the operation rooms rises as well, which also seems to play a role.<sup>23</sup> While Gruskay et al explained the seasonal influence of the infection rate in the warm season with a higher temperature, humidity and the 'July-Effect',<sup>19</sup> other studies could not verify this hypothesis and hence cast doubt on the 'July-Effect'.<sup>8,10,24</sup>

Contrary to previous findings concerning invasive surgeries with usually large wound areas, we hypothesise on the basis of the present study that there is no seasonal impact on the rate of postoperative infections in open carpal tunnel release surgery because of the small surgical approach and wound size.<sup>9,11,20</sup> At our institution, the incision for open carpal tunnel release is just approximately 3 cm. Moreover, this operative technique is performed with minimal subcutaneous dissection, which results in an overall small wound area.

Moreover, the question arises whether further measures can be implemented which might be useful to reduce the risk of surgical site infections. Kane et al recommend, especially during the warm season, a more thorough preoperative sterilisation procedure, a strict adherence to decontamination and sterilisation of the room personnel and equipment. Postoperatively, vigilance for the development of SSI should be increased.<sup>20</sup> An antibiotic prophylaxis was found not to have beneficial effects because both Bykowski et al and Harness et al could not observe a reduction of SSI when antibiotics were given before elective hand surgery<sup>25</sup> or open surgery of carpal tunnel syndrome.<sup>26</sup> A possibility to further reduce the incidence of SSI and WHD could be a surgical technique: the longitudinal 1.5 cm Mini-incision.

The study from Mardanpour et al demonstrated its satisfactory functional outcomes and a low complication rate.<sup>27</sup> Other studies concerning open carpal tunnel release surgery showed lower infection rates.<sup>28-30</sup>

Anthony et al emphasised that a consideration of the seasonal impact and an optimization of the timing of elective operations can be useful, not only to reduce the number of infections and thus to reduce the physical and psychological suffering of patients from these complications, but also to save costs for the health care system. Anthony et al states that via a reduction of 25% of all surgeries performed in the peak months, a reduction of more than 20% of SSI can be achieved as a consequence.<sup>10</sup>

Limitations of our study are the monocentric and retrospective study design. This setting does not eliminate the theoretical possibility that patients were treated by the family doctor in case of an infection or WHD and thus they are not appearing in the medical records of our institution. Furthermore, a retrospective study design, that is data collection exclusively through the medical records, renders an accurate assessment of the postoperative complication's severity difficult in some cases. This is also due to the fact that there is a fluid transition concerning the clinical appearance of postoperative complications ranging from fulminant infections over WHD to banal, physiological responses to the intervention, for example a small lymphedema. As a result of differentiation from non-pathological irritations at the surgical site and clinical signs of an infection, antibiotics are prescribed generously at our institution to prevent serious complications. Postoperative prescription of antibiotics was one definition criteria for SSI. This is the reason why in this study, the infection rate is high compared with other studies concerning open carpal tunnel release surgery with lower infection rates.<sup>27-29</sup> Another limitation is, that all the operations were not carried out from a single surgeon, but from many different surgeons with varying nursing staff.

Because the rate of serious infections is very low and there is no seasonal impact on the SSI rate in open carpal tunnel release surgery, we recommend no general adjustment of the operation timing according to the season. While there was no seasonal impact regarding SSI and infection-related revision surgery, we could, however, observe a significant seasonal influence on WHD and an association between male sex and the risk for WHD. We therefore advise considering the timing of this elective surgery with scheduling older male patients preferably during the cold season to prevent postoperative WHDs. Further prospective research concerning the impact of weather condition on the postoperative course would be necessary to define valid recommendations for everyday clinical practice.

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## CONFLICT OF INTEREST

All named authors hereby declare that they have no conflicts of interest to disclose.

## DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

## ETHICS STATEMENT

The research protocol was approved in advance by the ethical committee of the Province of Upper Austria. All of the methods performed in this study meet ethical standards and are consistent with the requirements of the ethics committee of the Province of Upper Austria (study number 1230/2019).

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