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Database analysis of the risk factors of bisphosphonate-related osteonecrosis of the jaw in Hungarian patients

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ABSTRACT

Objective Bisphosphonate-related osteonecrosis of the jaw (BRONJ) is a rare but serious side effect of bisphosphonates (BPs). Since this disease has no independent code in either of the diseases’ or in the medical procedures’ classifications, it is hard to estimate how many BP patients are affected.

Design A retrospective observational epidemiological registry-based study was carried out, using the data of the national service of Hungary on the incidence of BRONJ and related factors.

Setting A data analysis was performed, which is relevant for the whole Hungarian population from 2010 to 2014. The socioeconomic and medication data of 236207 BP patients were analysed, and a method was worked out to define BRONJ patients from the Hungarian BP population.

Primary and secondary outcome measures The incidences of BRONJ were analysed according to genders and the types of the BP drugs administered. The marginal interdependence between the types of BP drugs, modes of administration and main indication was calculated.

Results 340 BP patients (0.1%) developed BRONJ. The incidence of BRONJ in Hungary in the malignant indication of BPs is 0.9%, and 0.1% in the non-malignant indication, and the OR to develop BRONJ was OR=9.7 (95% CI 7.8 to 12.1) between them. Although more women developed BRONJ, the proportion of men was significantly higher than that of women. Steroids increase the risk of jaw osteonecrosis, and differences were also found between the BP drugs.

Conclusions Oncology indicated, intravenously administered and steroid comedicated BP therapies pose a high risk of developing BRONJ in the Hungarian population.

INTRODUCTION

Bisphosphonate-related osteonecrosis of the jaw (BRONJ) was first mentioned in the literature by Marx in 2003 and it was defined as a new disease by Ruggiero in 2004.1,2 The first guideline of the American Association of Oral and Maxillofacial Surgeons on BRONJ was published in 2007.3 This position paper was updated in 2009 and 2014.4,5 As per definition, BRONJ is present when there is denuded bone in the maxillofacial region which persists for >8 weeks from the diagnosis and

Strengths and limitations of this study

- Bisphosphonate-related osteonecrosis of the jaw (BRONJ) is a rare but very serious side effect of bisphosphonates (BPs), but it is hard to estimate how many BP patients are affected.
- A research method is developed to find BRONJ patients in the BP population.
- Since there is no independent code of disease or medical procedures for this disease, a selection bias can occur, which is the limitation of the study. The applied screening method narrows the number of potential BRONJ patients.
- The study was not registered in any databases of clinical studies.
- More studies are needed with a logistic regression model to find the interdependence of the analysed factors.

the patients have been treated with bisphosphonate (BP) despite no history of irradiation to the head and neck region.4 Since 2014 the disease group has been called medication-related ONJ (MRONJ), considering the antiresorptive and antiangiogenic drugs which potentially cause the disease.5

BRONJ is a characteristic side effect of BPs.6 The factors affecting the development of the necrosis are numerous. However, female gender and age seem to be risk factors by themselves.3,7 Potential risk factors include medical, local, demographical, genetic and usual risk factors (eg, tobacco use, obesity), as well as comorbidities (renal failure, anaemia, diabetes). Besides, it also poses a risk what kind of disease (malignant or non-malignant) is treated with BP. The potential, namely the drug type, the mode and the length of the administration of BP and the types of co-medications can also present a risk.4,8–12 Among comedication, corticosteroids, immunosuppressants, antioestrogens and chemotherapy can increase the risk of the development of BRONJ.13–18
Aims of the study
BRONJ has no independent code in the International Classification of Diseases (ICD) and related health problems, which makes it difficult to identify the patients who develop BRONJ (BRONJ patients). The aim of this work was to work out a method with which BRONJ patients can be chosen out of the patients treated with BPs (BP patients) whether they have a malignant or a non-malignant disease and to analyse the incidence and the risk factors of this side effect in the Hungarian population. It is hypothesised that there is a higher risk for developing BRONJ of the administration of BPs used in the malignant than in the non-malignant indication.

Ethics approval
The patients’ healthcare data (prescriptions’ data, ICD codes and codes of medical procedures) for the analyses were available from the National Healthcare Services Center’s (NHSC) database through a research contract. The NHSC collects and handles the data of the National Health Insurance Fund (NHIF) of Hungary as a basic task and, therefore, no ethics approval was needed for this study. The patients’ personal data were converted to identification number (IDs) and the aggregated medical data were used for the evaluation, which can be considered blinding. None of the patients can be identified in any ways for the members of the research group.

METHOD
Study design and patients
A retrospective observational epidemiological registry-based study was carried out. The incidences of BRONJ were analysed according to genders, and the types of the BP drugs. The marginal interdependence between the types of BP drugs, modes of administration and main indication was calculated.

Patient and public involvement
Patients and public were not involved in the design and conduct of the study.

Database and data collection
To obtain enough data for the analysis of this rare side effect, the study team decided to analyse the healthcare data of the Hungarian population. In Hungary, the NHIF is the only organisation to reimburse healthcare-related expenditures, including medicines and healthcare institutions, which gives a nationwide relevance for the analysis. To avoid the disturbing effect of the other drugs causing ONJ, the available data were collected from 1 January 2010 to 31 December 2014. Since the period of the screening covers the era of the BRONJ, this definition has been used throughout the manuscript. The selected time frame ensured that the earliest available data were analysed from the study start date, and the end date assures that only the effect of the BP drug group was analysed without the effect of other drugs which can cause MRONJ. The data were handled by professional experts of data handling from the NHSC, and they are coauthors of this paper (TB-L and ZP). The database of the NHSC is a validated database with limited access for users. This database is the basis of the Hungarian reimbursement system. Since the data analysed were extracted from a validated database, a group of randomly selected patients were chosen for the validation based on their coded personal healthcare data and the prescribed medicines.

First, the prescription data of the BP type medicines under Anatomical Therapeutic Chemical (ATC Classification System) codes were collected as follows: M05BA—bisphosphonates and M05BB—bisphosphonate combinations. The prescription data contain the ICD code, which stands for the main indication of the use of the medication. This screen resulted in the BP population of Hungary. BRONJ patients were selected from the BP population using the NHIF patient care database. The selected ICD and International Classification of Procedures in Medicine (ICPM and related health problems) codes are shown in figure 1. In this study, the BP patients selected according to both ICD and ICPM codes were defined as BRONJ patients. Irradiation to the head and neck region was considered an exclusion criterion. The ICPM codes of the irradiations were defined from the inpatient and outpatient care ICPM database of Hungary. NHIF refers to the ICPM codes as a basis of reimbursement. The parameters in the BRONJ patients’ group were analysed until the first ICD or ICPM code in connection with BRONJ appeared. The no BRONJ group consists of the patients chosen from the database according to the ATC code of the prescribed medicine and have not developed BRONJ during the study time period. In this group, these parameters were taken into consideration for the whole time period of the study.

The effect of BPs was analysed according to drug types (different types of BP drugs: alendronate, clodronate, ibandronate, pamidronate, risedronate and zoledronic acid) and main indications. Malignant (M) and non-malignant (NM) groups of indications were separated on the basis of the name, package and reimbursement technique of the dispensed BP drug.19 The BP medicines with an indication of advanced malignancies involving bone (eg, the skeletal events of breast cancer, prostate cancer or multiple myeloma or tumour-induced hypercalcaemia) were administered to M patients, and NM patients were treated with BPs for postmenopausal, male or glucocorticoid-induced osteoporosis or Paget’s disease of the bone. The patients included were grouped into Oral and Intravenous groups according to the mode of administration of the BP. In the Oral group, patients took their BP medicines orally. In the Intravenous group, BP drugs were administered to the patients intravenously or both intravenously and orally because the risk of BRONJ with intravenous BPs can be 100–1000 times higher than the risk with oral BPs.5 In the case of patients taking oral BPs, a 182-day time shift was required between the first BP dispensing and the onset of the disease.7,8 No time shift
was required in the case of intravenous BPs because these medicines might increase the risk of BRONJ right after the first administration.

In this study, therapy switch was defined when another BP drug type and/or the same drug in another route was administered to a predefined patient. The doses of the different drug types were made comparable by using a relative total dose (RTD). Defined daily dose of drugs were used to calculate days of therapy (DOTs) of the medications. Dividing the DOT amounts of the dispensed BP drugs for every patient with the days spent at risk in the study time period gives the amount of the RTD. The days spent at risk means the study time period for non-necrosis patients. For necrosis patients, it means the days spent on September 21, 2022 by guest. Protected by copyright.http://bmjopen.bmj.com/ BMJ Open: first published as 10.1136/bmjopen-2018-025600 on 22 May 2019. Downloaded from http://bmjopen.bmj.com/ on September 21, 2022 by guest. Protected by copyright.

**Figure 1** Method of the definition of the Hungarian BP and BRONJ population. This figure represents the method which has been worked out to identify BRONJ patients from the Hungarian BP population. The BP users were screened according to the ATC code of the prescribed medicine from 2010 to 2014. After the exclusion of the patients who were irradiated in the head and neck region, a dual screen of the BRONJ patients was applied. According to the definition of this study, the BRONJ patients group consists of those patients whose data contain both the ICD and the ICPM codes regarding BRONJ. ATC, Anatomical Therapeutic Chemical; BP, bisphosphonate; BRONJ, bisphosphonate-related osteonecrosis of the jaw; ICD, International Classification of Diseases; ICPM, International Classification of Procedures in Medicine.

| Number of patients | Age |
|--------------------|-----|
| Number | BRONJ (%) | No BRONJ (%) | Total | BRONJ (±SD) | No BRONJ (±SD) | Total (±SD) |
| Male patients | 94 (0.3) | 31802 (99.7) | 31896 | 66.2 (61.0–71.5) | 67.4 (61.2–73.6) | 67.4 (61.2–73.6) |
| Female patients | 246 (0.1) | 204009 (99.9) | 206475 | 65.0 (60.0–70.0) | 68.7 (63.7–73.7) | 68.7 (63.7–73.7) |
| Total | 340 (0.1) | 235811 (99.9) | 239212 | 65.4 (60.3–70.4) | 68.5 (63.3–73.7) | 68.5 (63.3–73.7) |

Table 1: Age and gender characteristics of the study population

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[1] American Association of Oral and Maxillofacial Surgeons Position Paper on Bisphosphonate- related Osteonecrosis of the Jaws. Advisory Task Force on Bisphosphonate- related Osteonecrosis of the Jaws. J Oral Maxillofac Surg 85:369, 2007.
between the beginning of the study and the first occurrence of an ICD or ICPM code related to the BRONJ.

The BP patients were selected from the study population to whom steroids (ATC group H02) were dispensed any number of times to analyse the effect of corticosteroid comedication. The risk increasing effect of the RTD of the BPs and the BP drug types were analysed in this group.

### Statistical analysis

IBM SPSS Statistics V.20 programme was applied for the statistical analyses. Evaluation was performed by descriptive analysis, the kind of distribution of the data was checked by Kolgomorov-Smirnov test. For the comparisons of the proportions of the BRONJ caused by the different drug compounds, administration modes and main indications, Student’s t-test was applied. Marginal interdependence between the variables (genders, drug compounds and so on) was calculated by counting marginal ORs and 95% CIs. Mood’s median test was used when the non-normally distributed data (RTDs of the drugs) were compared between patients’ groups. The χ² test was selected to analyse the

**Table 2** Comparison of the main indications with administration routes and therapy switch of the bisphosphonates

| Gender and main indication of bisphosphonates* | BRONJ (%) | No BRONJ (%) | OR (95% CI) | P value |
|-----------------------------------------------|-----------|--------------|-------------|---------|
| **Male**                                      |           |              |             |         |
| Malignant                                     | 68 (0.9)  | 7955 (99.1)  | 7.3 (4.7 to 11.4) | <0.0001 |
| Non-malignant                                 | 28 (0.1)  | 24 046 (99.9) |             |         |
| **Female**                                    |           |              |             |         |
| Malignant                                     | 65 (1.0)  | 6465 (99.0)  | 10.9 (8.2 to 14.5) | <0.0001 |
| Non-malignant                                 | 183 (0.1) | 198 220 (99.9)|             |         |

| Main indication and route of administration of bisphosphonates |

| Gender and main indication of bisphosphonates* | BRONJ (%) | No BRONJ (%) | OR (95% CI) | P value |
|-----------------------------------------------|-----------|--------------|-------------|---------|
| **Malignant and non-malignant disease**       |           |              |             |         |
| Intravenous                                   | 4 (0.7)   | 604 (99.3)   | 3.2 (0.2 to 59.8) | 0.43    |
| Oral                                          | 0 (0.0)   | 215 (100.0)  |             |         |
| Total                                         | 4 (0.5)   | 819 (99.5)   |             |         |
| **Malignant disease**                         |           |              |             |         |
| Intravenous                                   | 111 (1.2) | 9409 (98.8)  | 2.8 (1.7 to 4.5) | 0.0001  |
| Oral                                          | 18 (0.4)  | 4210 (99.6)  |             |         |
| Total                                         | 129 (0.9) | 13 619 (99.1)|             |         |
| **Non-malignant disease**                     |           |              |             |         |
| Intravenous                                   | 67 (0.1)  | 51 158 (99.9)| 1.7 (1.3 to 2.2) | 0.0004  |
| Oral                                          | 140 (0.1) | 170 271 (99.9)|             |         |
| Total                                         | 207 (0.1) | 221 429 (99.9)|             |         |
| **Total**                                     | 340 (0.1) | 235 864 (99.9)|             |         |

| Therapy switch in the groups of oral and intravenous administrations |

| Oral bisphosphonates | BRONJ (%) | No BRONJ (%) | OR (95% CI) | P value |
|-----------------------|-----------|--------------|-------------|---------|
| 1 type                | 146 (0.1) | 151 390 (99.9)| 1.9 (1.0 to 3.4) | 0.04    |
| <1 type               | 12 (0.1)  | 23 285 (99.9) |             |         |
| Total                 | 158 (0.1) | 174 675 (99.9)|             |         |

| Intravenous bisphosphonates | BRONJ (%) | No BRONJ (%) | OR (95% CI) | P value |
|-----------------------------|-----------|--------------|-------------|---------|
| 1 type                      | 167 (0.3) | 58 102 (99.7)| 0.9 (0.5 to 1.5) | 0.69    |
| <1 type                     | 15 (0.5)  | 3069 (99.5)  |             |         |
| Total                       | 182 (0.3) | 61 171 (99.7)|             |         |

Bold values are highlighting results.

*In malignant and non-malignant groups, patients taking bisphosphonates in both indications are present.

BRONJ, bisphosphonate-related osteonecrosis of the jaw.
difference between categorical variables. The level of significance was p≤0.05.

RESULTS
Using the method developed for this study, the Hungarian BP population in the study time period amounted to 236207 patients. As a result of the two screening criteria, the BRONJ patients’ number came up to 340 (0.1%). The age and gender characteristics of the study population are presented in table 1, while the comparison of the basic indications and the routes of administration of BPs are presented in table 2. Our results show significantly more BRONJ cases in male than in female BP patients, p<0.001.

There was a significant difference between the BRONJ and the No BRONJ groups from the point of view of age, p<0.001. In the BRONJ group, the proportion of female patients (F/M: 72.4%/27.7%) was significantly lower than in the whole study population (F/M: 86.5%/13.5%), p<0.001. The male patients developed BRONJ with a 2.5 times higher odds (95% CI 1.9 to 3.1, p<0.001) than female patients. The proportion of oncology patients was higher in male than in female patients (F/M: 72.4%/27.7%) was significantly lower than that in the total study population (F/M: 86.5%/13.5%), p<0.001. In the BRONJ group, the proportion of female patients was significantly lower than those in the study population. In the alendronate and risedronate groups, the proportion of BRONJ patients was significantly lower than in the total population.

The mean RTDs of the dispensed BPs are presented in table 4 according to drug types. The difference in the proportion of BRONJ cases was defined between each pair of drug types. Table 5 gives the p values and ORs. This shows whether a drug compound has a stronger effect on the development of BRONJ than another.

Glucocorticoid comedication
In the BP patients’ group treated with glucocorticoids (steroid BP group; n=44784), the proportion of BRONJ (80 patients, 0.2%) was significantly higher in the steroid non-taker BP group (n=191423, BRONJ: 260 patients, 0.1%) (p=0.013), OR=1.3 (95% CI 1.0 to 1.7, p=0.03). In

| Drug and administration route | BRONJ (%) | No BRONJ (%) | Total | P value | Necroses |
|------------------------------|-----------|--------------|-------|---------|----------|
| Clodronate oral              | 23 (6.8)  | 4588 (1.9)   | 4611  | <0.001  | More necroses |
| Clodronate intravenous       | 0 (0.0)   | 65 (0.0)     | 65    | 0.75    | Not significant |
| Ibandronate oral             | 29 (8.5)  | 11408 (4.8)  | 11437 | 0.003   | More necroses |
| Ibandronate intravenous      | 44 (12.9) | 35850 (15.2) | 35894 | 0.31    | Not significant |
| Pamidronate intravenous      | 11 (3.2)  | 1223 (0.5)   | 1234  | <0.001  | More necroses |
| Alendronate oral             | 133 (39.1)| 142075 (60.2)| 142208| <0.001  | Fewer necroses |
| Risedronate oral             | 46 (13.5) | 66451 (28.2) | 66497 | <0.001  | Fewer necroses |
| Zoledronic acid intravenous  | 142 (41.8)| 27117 (11.5) | 27259 | <0.001  | More necroses |
| Total                        | 340 (100.0)| 235867 (100.0)| 236207| NA      | Basis of comparison |

Whether the given drug compound and administration route result in more or fewer necroses than it was found in the whole study population.

BRONJ, bisphosphonate-related osteonecrosis of the jaw.
There is a 12.3% OR (95% CI 8.0 to 19.0, p<0.001) between the steroid BP group and the total steroid BP population. In the NM (1.3%, p<0.001), significantly higher than those of the total NM indications (n=283, BRONJ 0.71%, p=0.04), and in the 662 steroid BP patients occurred (0.1%), significantly more steroid BP cases among the patients treated with BPs both in M and in NM indications (n=283, BRONJ 0.71%, p=0.04), and in M indications there were 37 BRONJ cases out of 2839 patients (1.3%, p<0.001), significantly higher than those of the total steroid BP population. In the NM group, 41 BRONJ cases out of 41662 steroid BP patients occurred (0.1%), significantly fewer than in the total steroid BP group (p=0.0016). There is a 12.3 OR (95% CI 8.0 to 19.0, p<0.001) between the M and NM steroid patients’ groups to develop BRONJ. There is no significant difference between the group of both indications and the M BP groups (p=0.39), but the result of the M BP group is significantly higher than that of the NM indication group (p<0.001).

Carrying out a Mood’s median test, the median RTD of BPs in the patients who took steroids with BPs (median RTD: 0.481 [0.2–0.9]) does not differ from that of those patients who did not take steroids (median RTD: 0.473 [0.2–1.0]). Steroid BRONJ patients’ (n=80, median RTD of BPs: 0.771 [0.5–1.11]) median total RTD of BPs was significantly higher than that of the No BRONJ steroid patients (n=41704, the median RTD of BPs was 0.481 [0.2–0.91]) (p<0.001). The RTD of BP is higher in the steroid BRONJ group in the case of oral clodronate, parenteral ibandronate, pamidronate and zoledronic acid. This difference is only significant in the zoledronic acid BP group, p<0.001. The RTD of BP is lower in the steroid BP group of patients in the oral ibandronate, alendronate and risedronate BP groups, in which only risendronate is significant: p=0.001.

### DISCUSSION

BRONJ has not been studied in the Hungarian population yet. The higher number of BRONJ in male patients is attributed to the fact that there is a higher proportion of male than female oncology patients in the Hungarian BP population. The number of female BRONJ patients was higher because women make up more of the total BP population (postmenopausal osteoporosis). According to the results, the proportion of male BRONJ patients was higher even in the NM indication of BPs than that of female BRONJ patients. The underlying cause was presumably the increasing use of intravenous BPs because of non-adherence and the presence of other (eg, local) risk factors. Since the database of the Hungarian NHIF provides the medical and the main demographical data of the patients, but the local, genetic and usual risk factors are not included, these factors were not accessible for the analyses.

The results of the studies on the incidence of BRONJ cover a wide range. The results of this study are comparable to the international results of malignant (0.9%/0.8%–11%) and also non-malignant indications of BPs (0.1%/0.001%–0.7%). The number of patients with osteoporosis in Hungary is increasing. These patients’ adherence is very low and a relatively high number of patients receive no adequate treatment. The latter results in the under treatment of these patients, but side effects or medical combinations which increase the risks of side effects might occur in the long term.

Switching therapy (using more than one type of BP drug or using the same drug in another administration route) in a group of a single drug type usually increases the risk of side effects. From the references, it can be concluded that in the case of intravenous BPs, the BP type and the length of therapy have a stronger effect than the switch itself. In this study population, more BRONJ occurred in the patients’ group treated with one type of oral BPs than in the switched group, and there were more BRONJ cases in the switched intravenous BP group than in the non-switched group. Oral BPs are mainly used in non-malignant indications, and the length of therapy might have a stronger effect on the risk of BRONJ than the switching therapy. In oncology, clodronate might be used to increase the effect of other intravenous BPs, or the less effective BP might be changed for a more effective one to...
which showed a 4%.

The administration of pamidronate was found in the present study among the patients who were administered pamidronate than in another study. In this study, which might be the result of the status of the Hungarian patients with osteoporosis: the number on developing BRONJ than oral and non-aminoBPs, according to the order of potency. There are fewer BRONJ cases in clodronate, risedronate and oral ibandronate than alendronate, which is the result of the potency and the widespread use of alendronate. Alendronate shows a lower risk than intravenous BPs, while intravenous ibandronate has a lower risk than pamidronate and zoledronic acid.

### Table 5 Difference of proportion of BRONJ in the drug groups (on the basis of the results of table 3)

| Drug groups | CLO intravenous (95% CI) | IBA oral (95% CI) | IBA intravenous (95% CI) | PAM (95% CI) | ALE (95% CI) | RIS (95% CI) | ZOL (95% CI) |
|-------------|--------------------------|-------------------|--------------------------|-------------|-------------|-------------|-------------|
| CLO oral    | OR: 1.5 (0.1 to 24.8), p=0.78 | OR: 0.5 (0.3 to 0.9), p=0.02 | OR: 0.2 (0.1 to 0.4), p≤ 0.001 | OR: 1.8 (0.9 to 3.7), p=0.11 | OR: 0.2 (0.1 to 0.3), p<0.001 | OR: 0.1 (0.1 to 0.2), p<0.001 | OR: 1.0 (0.7 to 1.6), p=0.85 |
| CLO intravenous* | OR: 0.2 (0.0 to 2.7), p=0.20 | OR: 1.2 (0.1 to 21.1), p=0.89 | OR: 0.1 (0.1 to 2.0), p=0.14 | OR: 0.1 (0.1 to 1.5), p=0.09 | OR: 0.1 (0.0 to 1.5), p=0.79 |
| IBA oral | OR: 0.5 (0.3 to 0.8), p=0.002 | OR: 3.5 (1.7 to 7.1), p<0.001 | OR: 0.4 (0.2 to 0.6), p<0.001 | OR: 0.3 (0.2 to 0.4), p<0.001 | OR: 2.1 (1.4 to 3.1), p<0.001 |
| IBA intravenous | OR: 7.3 (3.7 to 14.2), p<0.001 | OR: 0.8 (0.5 to 1.1), p=0.12 | OR: 0.6 (0.4 to 0.9), p=0.006 | OR: 4.3 (3.0 to 6.0), p<0.001 |
| PAM | OR: 0.1 (0.1 to 0.2), p<0.001 | OR: 0.1 (0.0 to 0.1), p<0.001 | OR: 0.6 (0.3 to 1.1), p=0.09 |
| ALE | OR: 0.7 (0.5 to 1.0), p=0.08 | OR: 5.6 (4.4 to 7.1), p<0.001 |
| RIS | OR: 7.6 (5.4 to 10.6), p<0.001 |

Bold values are statistically significant.

This table shows whether a drug has a stronger effect to develop BRONJ than the other one.

*In the case of intravenous CLO, 0.5 cases were added to each patients’ number in the equation to be able to count ORs.

ALE, alendronate; BRONJ, bisphosphonate-related osteonecrosis of the jaw; CLO, clodronate; IBA, ibandronate; PAM, pamidronate; RIS, risedronate; ZOL, zoledronic acid.

improve patient status in the short term. Non-aminoBP clodronate has no proven risk-increasing effect, but the cumulative effect of BPs cannot be excluded.40 41

In contrast to previous studies, our study illustrates that there were more BRONJ patients in the group of alendronate and ibandronate patients during the study period in Hungary. BRONJ in the weekly administered alendronate patients is 0.01%–0.04%. This ratio was 0.09% in Hungary. BRONJ in the weekly administered alendronate and ibandronate patients during the study period was not significantly higher. In risedronate patients, BRONJ patients had a lower total dose, but the cumulative effect of BPs cannot be excluded.40 41 In NM indications, the total length of the therapy has a stronger effect on the development of the side effects than the total dose.46 In this study, BRONJ patients were administered a significantly higher total dose of BP than no BRONJ patients in the oral clodronate, the pamidronate and the zoledronic acid groups. In ibandronate and alendronate patients, the total dose of BP in BRONJ patients was not significantly higher. In risedronate patients, BRONJ patients had a lower total dose, but not significantly. In this case, we hypothesise the presence of other non-drug-dependent risk factors.

According to the results of other studies, BRONJ is present in approximately 0.7%–10% of zoledronic acid oncology patients. A lower percentage (1.2%) was found in the Hungarian BP population.

There is a higher risk of BRONJ in a given BP drug group with a higher total dose in both main indications of BPs. In NM indications, the total length of the therapy has a stronger effect on the development of the side effects than the total dose. In this study, BRONJ patients were administered a significantly higher total dose of BP than no BRONJ patients in the oral clodronate, the pamidronate and the zoledronic acid groups. In ibandronate and alendronate patients, the total dose of BP in BRONJ patients was not significantly higher. In risedronate patients, BRONJ patients had a lower total dose, but not significantly. In this case, we hypothesise the presence of other non-drug-dependent risk factors.
Glucocorticoids increase the risk of BRONJ. The necrosis might occur earlier, it is more severe and reacts slower to the discarding of BP. In steroid BP patients, there is a significantly higher proportion of BRONJ patients than in the whole BP population. There is a higher risk of developing BRONJ when a higher dose of BP is administered to a patient with steroid comedication, and there are differences between the BP drugs. Alendronate and risedronate BP dose is higher in the steroid No BRONJ group than in the steroid BRONJ group, and the zoledronic acid dose is lower, respectively. Alendronate and risedronate cumulative doses possibly have a weaker effect on BRONJ than the steroid comedication, and in the case of zoledronic acid, this effect is reversed.

Limitations
The database which this research group could access did not include dose, prescription or medication data from the period before 2010. From the risk factors of BRONJ, cumulative doses and the length of the BP therapy were not analysable, and the exposure bias has not been considered in the absence of relevant data. This study was not registered to any databases of clinical trials.

Since there are no independent ICD and ICPM codes of this disease, a selection bias can occur, which is the limitation of the study. The applied screening method narrows the number of potential BRONJ patients.

The effect of the BP drugs were analysed without considering the effect of other risk factors and the interdependence of the analysed risk factors. The single effect of the drugs, the main indication and the administration forms were compared. To analyse the combined effect of these factors, the application of a logistic regression model would be necessary.

CONCLUSIONS
These data are the first to have defined the incidence data of BRONJ in the Hungarian BP population according to the main indications of BPs and routes of administration. Our results show differences between BP drugs in their potential to cause BRONJ independently of their doses. Duality was typical in gender, main indication and also in the mode of administration of BPs. Male, oncology and intravenous BP patients were at a higher risk of developing BRONJ, but the significantly higher number of the opposite population of these groups resulted in a higher number of BRONJ in the groups of female patients, osteoporosis and oral BP patients. In the Hungarian BP population, the risk increasing main factors of BRONJ were corticosteroid comedication and BPs with malignant indication. More studies are needed to find the interdependence of the analysed factors.

Contributors
The revised manuscript has been read and approved by all authors. All persons listed as authors have contributed to preparing the manuscript, and no persons other than the authors listed have contributed significantly to the preparation of the revision. BH and MV designed, directed and supervised the project with the help of ZP. TB-L and ZP collected the data from the database of the National Healthcare Services Center of Hungary. The data collection was supported by EVK. AM performed the statistical analyses. The data interpretation was performed by TB-L, ZP and EVK with the help of AM. All authors discussed the results, and EVK wrote the manuscript with input from all authors. BH and MV revised the manuscript.

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The authors are not able to provide the full study dataset, since the database is the property of the National Healthcare Services Center of Hungary, and these data are not free for public application. The raw data are not public; the authors had an access to this database based on a contract between the researcher (Semmelweis University, Budapest, Hungary) and the NHSC.

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