



Adsorbent Dressings from Sodium Carboxymethyl Cellulose With Silver Ions in Primary Knee Arthroplasty: A Randomized Trial

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Background. The ideal wound dressing should have complex positive affect on a postoperative wound healing: absorb excessive wound exudate, allow adequate gas exchange, prevent secondary infectious complications, create optimal humidity, be durable and not to restrict patients' mobility, which is crucial for early mobilization after total knee arthroplasty. We carried out this research to asses the effectiveness and safety of contemporary adhesive wound dressings and if they do have the abovementioned qualities.

Aim – to assess the effect of using absorbing wound dressing made from sodium carboxymethyl cellulose with silver ions on the quality of rehabilitation and the rate of superficial infection occurrence in patients who underwent total knee joint arthroplasty.

Methods. This prospective randomized (simple randomization) paralleled open study included 200 patients with terminal stage knee arthritis, who required total knee joint arthroplasty. Patients were divided into three groups, in two of the groups the innovate wound dressing made from sodium carboxymethyl cellulose with silver ions was used, in the third group traditional wound dressing was used.

Results. In the course of this study, it was confirmed that there was no statistically significant difference in pain syndrome intensity in the early postoperative period or Knee Society Score (KSS) at 3 months postoperatively in regard of type of wound dressing and time of its application. Subjectively the most comfortable wound cover method for the patients was the usage of adhesive dressings with silver impregnation from the first day postoperatively. As complications we observed epidermal blistering under the dressing, superficial wound necrosis, superficial wound infection and formation of prominent and rough postoperative scars. The highest rate of blistering was observed in patients with traditional patch wound dressing.

Conclusions. The usage of absorbing wound dressing made from sodium carboxymethyl cellulose with silver ions in our current study did not affect the rate of infectious complications and did not have any negative effects on rehabilitation. The usage of innovate dressings reduced the rate of epidermal blistering associated with dressings.

Keywords: adhesive wound dressing, surgical infection, wound infection, total knee arthroplasty, complications.

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Применение адсорбирующих повязок из натрийкарбоксиметилцеллюлозы с ионами серебра в первичном эндопротезировании коленного сустава: рандомизированное исследование

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Актуальность. Идеальные перевязочные материалы должны оказывать комплексное положительное влияние на эпителизирующуюся послеоперационную рану — эффективно удалять избыток раневого экссудата, обеспечивать адекватный газообмен между раной и окружающей средой, предотвращать вторичное инфицирование раны, способствовать созданию оптимальной влажности раневой поверхности, иметь достаточную механическую прочность, не стеснять движений пациента, что является крайне важным в ранней реабилитации после операций эндопротезирования коленного сустава.

Цель — оценить влияние использования адсорбирующих повязок из натрийкарбоксиметилцеллюлозы с ионами серебра на качество реабилитации и частоту развития поверхностной инфекции в раннем послеоперационном периоде у пациентов, перенесших операцию тотального эндопротезирования коленного сустава.

Материал и методы. В проспективное рандомизированное (простая рандомизация) параллельное открытое исследование было включено 200 больных с терминальной стадией гонартроза, нуждающихся в выполнении первичного эндопротезирования коленного сустава. Пациенты были разделены на три группы, в двух из которых были использованы инновационные повязки из карбоксиметилцеллюлозы, импрегнированной серебром, а в третьей перевязки осуществляли традиционным образом.

Результаты. В ходе исследования было подтверждено, что независимо от вида повязок и времени их наложения нет статистически значимых различий в степени выраженности болевого синдрома в раннем послеоперационном периоде и показателях функции коленного сустава по шкале KSS через 3 мес. после операции. Субъективно наиболее комфортным для пациентов вариантом укрытия послеоперационной раны стало использование адгезивных повязок, импрегнированных серебром, с первого дня после операции. В качестве осложнений были зафиксированы развитие эпидермальных пузырей под повязкой, некроз краев раны, поверхностная инфекция области хирургического вмешательства и формирование грубого послеоперационного рубца. Развитие блистеринга (формирование эпидермальных пузырей) чаще возникало у тех пациентов, у которых были использованы классические клейкие повязки.

Заключение. Использование адсорбирующих повязок из натрийкарбоксиметилцеллюлозы с ионами серебра в проведенном нами исследовании не повлияло на количество гнойно-септических осложнений у пациентов и не оказало негативного влияния на реабилитацию. Использование современных повязок позволило снизить частоту развития эпидермальных пузырей под повязкой.

Ключевые слова: адгезивные повязки, хирургическая инфекция, раневая инфекция, эндопротезирование коленного сустава, осложнения.

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Background

Over the past decades, significant changes occurred in conceptual approaches to the use of dressings (wound coverings) in everyday surgical practice. Thus, the dressing paradigm changed not only in the aspect of “when and how many times to dress?” but also “what material?” There is a constant search and development of not only materials for the manufacture of dressings, but also coatings which, being in direct contact with the wound, should optimize epithelialization [1]. Despite the rapid development of medical technologies, the problem of healing and predictable safe management of postoperative wounds has not yet been resolved [2].

Theoretically, ideal dressings should have a complex positive effect on the postoperative wound, remove effectively excess wound exudates and its toxic components, ensure adequate gas exchange between the wound and the environment, prevent secondary infection of the wound and contamination of environmental objects, contribute to the creation of optimal moisture in the wound surface, have sufficient mechanical strength, and do not hamper the patient’s movements, which is very critical in the period of early rehabilitation after arthroplasty of large joints [3].

Publications covering this issue can be divided into three main categories.

Group 1 includes several prospective randomized trials and reviews showing that absorbent wound dressings, which are more commonly used to treat wounds in general and purulent surgery, also demonstrate good results when used in patients who have undergone elective orthopedic interventions [4, 5, 6, 7, 8].

Group 2 includes studies that did not reveal a significant difference between different wound dressings in terms of the incidence of infectious complications, healing time, pathological scarring, pain intensity, patient comfort, or ease of dressing change [6, 9].

Group 3 includes studies indicating the negative aspects of new dressings. For example, dressings with a sealing effect can lead to excessive exudate exposure to the wound, and an excessively humid environment contributes to skin damage and bacterial infection of the postoperative wound [10].

Such an amount of disparate data necessitated the evaluation and statistical confirmation of the efficiency and safety of using modern adhesive dressings made of sodium carboxymethyl cellulose with silver ions in total knee arthroplasty.

This study aimed to evaluate the effect of the use of sodium carboxymethyl cellulose adsorbent dressings with silver ions on the quality of rehabilitation and incidence of superficial infection in the early postoperative period in patients after total knee arthroplasty.

Methods

Study design

A prospective, randomized, parallel, open, single center study (simple randomization) was performed.

The study was conducted in the clinic of the R.R. Vreden National Medical Research Center for Traumatology and Orthopedics from April to December 2019. The study included 200 patients with end-stage deforming knee arthrosis who required primary uncomplicated total knee arthroplasty.

The inclusion criteria were as follows: patients with stage III gonarthrosis according to Kosinskaya’s classification, aged 50–75 years, without restrictions on sex and body mass index.

The exclusion criteria were as follows:

- Patients with extensive defects of the bones that form the knee joint, requiring various types of plastic interventions on the knee joint and endoprostheses with increased frontal stabilization.
- Patients with skin diseases even in remission, diabetes, history of surgery, or infectious complications on the prosthetic joint (Fig. 1).

Patients

Among the patients examined, women predominated both in the general array and in all three groups. All clinical groups were comparable in terms of sex and age ($p > 0.05$) (Table 1).

Surgical technique

All patients underwent surgery under spinal anesthesia using bupivacaine solution. Thirty minutes before surgery, 1.5 g of tranexamic acid was administered intravenously. The surgery was performed using a pneuotourniquet that was inflated in the position of maximum flexion in the knee joint, creating a pressure of 270–300 mm Hg in the cuff. In all patients, we used an anterior approach to the knee joint. Using a standard set of tools, the necessary elements of soft tissue release in the knee joint were made, a bed was prepared for the endoprosthesis components, and their cement retention was performed. In the knee joint flexion position, the joint capsule and subcutaneous adipose tissue were

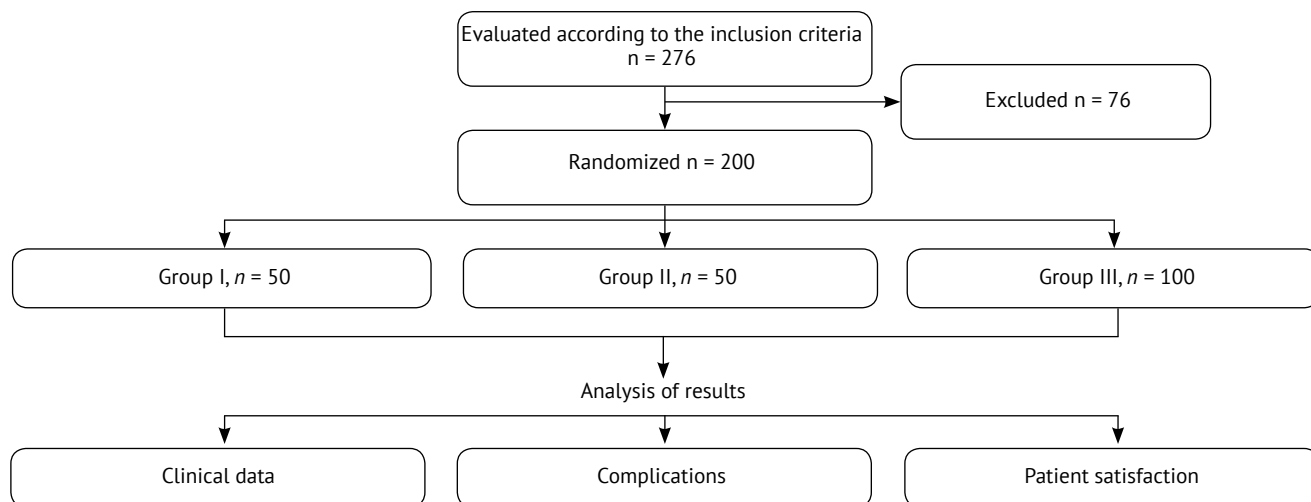


Fig. 1. Study flowchart

Table 1

Distribution of patients by sex and age

Parameter	Group		
	I	II	III
Sex			
female	45 (90%)	43 (86%)	82 (82%)
male	15 (10%)	7 (14%)	18 (18%)
Age, years	64.2 (Me 65.0 ± 7.2)	63.9 (Me 66.0 ± 10.1)	62.1 (Me 62.0 ± 10.3)

p > 0.05.

sewn with a continuous twisted suture with a braided bioresorbable suture. The skin was sewn with a non-absorbable, removable polycapromide monofilament suture using a continuous Donati suture. Drainage of the knee joint cavity was not performed in the study patients. In all patients in the postoperative period, a standardized thromboprophylaxis regimen was used (low-molecular-weight heparin with transition to tablet forms of anticoagulants and the use of compression garments).

All patients were randomly distributed into three groups, with different types of wound dressings used in the postoperative period.

In group I (n = 50), the postoperative wound was covered with an adhesive bandage of sodium carboxymethyl cellulose with silver ions Aquacel Ag Surgical (ConvaTec Inc., UK) in the operating room immediately after wound suturing. During hospi-

talization, staged dressings were not performed until discharge (Fig. 2).

In group II (n = 50), while in the operating room, the wound was covered with a sterile gauze dressing, which was fixed to the skin with an adhesive sticker Curapor (Lohman & Rausher International, Germany). On the next day after surgery, during the first dressing and treatment of the postoperative wound with antiseptic solutions, the wound was covered with a bandage of sodium carboxymethyl cellulose with silver ions Aquacel Ag Surgical. As in group I, staged dressings were not performed until discharge.

In groups I and II, the sodium carboxymethyl cellulose dressing was changed postoperatively. In patients with visual wetting of the absorbent layer reaching 50%, they were excluded from the study (Fig. 3).

In group III ($n = 100$), the wound was covered with sterile gauze dressing, which was fixed to the skin with an adhesive Curapor sticker. During hospitalization, wounds in this group were dressed once every 2 days; postoperative wounds were treated with aqueous antiseptic solutions and complete replacement of the gauze bandage. This group was included as the comparison group (Fig. 4).

Postoperatively, the clinical parameters, such as the emergence of blistering, number of dressings required during hospitalization, number of early postoperative infectious complications, effect of the used dressings on rehabilitation, and severity of pain syndrome according to visual analog scale (VAS), were assessed in all patients. The subjective assessment of patients was also taken into account.



Fig. 2. View of the knee after total knee arthroplasty with Aquacel Ag Surgical dressing



Fig. 3. View of the knee after total knee arthroplasty with Aquacel Ag Surgical dressing with leakage more than 50%

At 90–120 days after surgery, all patients were interviewed by phone to ensure that there were no infectious complications after discharge, and knee joint function was assessed using the Knee Society Score (KSS).



Fig. 4. View of the knee after total knee arthroplasty with a gauze dressing

Statistical analysis

After receiving the initial patient data, spreadsheets were compiled using the Microsoft Excel computer program. For statistical processing of data, we used Past ver.3.17. All data were tested for compliance with the normal (Gaussian) distribution using the Shapiro–Wilk and Kolmogorov–Smirnov tests. Data that did not follow a normal distribution were evaluated using nonparametric statistics. The samples were compared using the Mann–Whitney and Kruskal–Wallis tests. To search for correlation, Pearson’s linear correlation test and Spearman’s rank correlation test were used.

Results

Pain syndrome is one of the subjective indicators that determine the patient’s well-being and his/her satisfaction with the surgical intervention. This parameter was analyzed on a VAS. To exclude or confirm the assumption of a possible relationship between the intensity of the pain syndrome and the type of dressings, both of these parameters were analyzed statistically. Accordingly, regardless of the type of bandages and their application time, in all groups, no significant differences ($p = 0.09–0.12$) were noted in the severity of pain syndrome in the early postoperative period (Fig. 5).

Moreover, analysis was conducted to determine a possible statistical relationship between the pa-

rameters of the knee joint function on the KSS scale before surgery and 3 months after surgery. With identical baseline indicators in the immediate postoperative period, slight differences were found in the absolute numerical values in all groups; however, no significant differences were observed ($p > 0.05$). In group I at month 3, the average value on the KSS scale was 77.1 (Me 75.0 ± 1.5), and it was the lowest among the comparison groups. In groups II and III, values were almost comparable, with 80.1 (Me 77.0 ± 2.5) and 79.0 (Me 77.0 ± 2.7), respectively (Fig. 6).

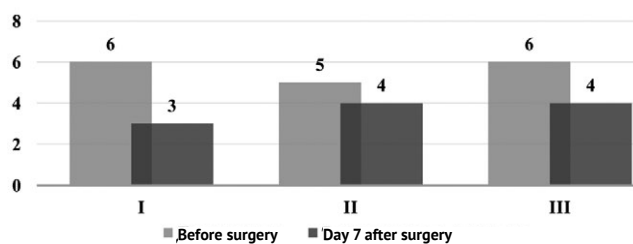


Fig. 5. VAS before and after surgery

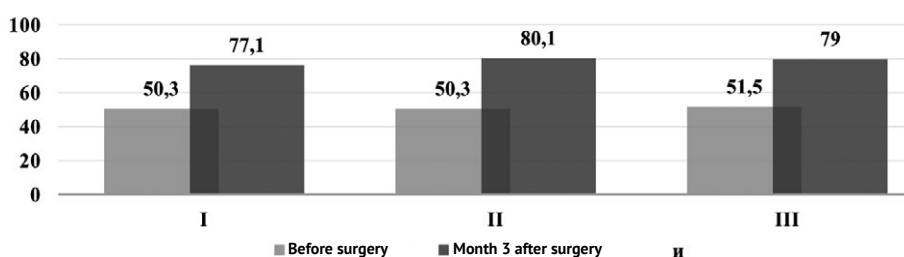


Fig. 6. Knee function according to the KSS

Complications

A well-known complication of the use of adhesive dressings is the development of epidermal blisters around the wound, referred to as blistering. In the early postoperative period, we managed to establish that the blistering phenomena occurred more often in group III, whose wounds were covered with classic adhesive bandages Curapor ($n = 11$). This finding was not only clinically obvious, but also had a significant justification. In group I, the described type of complications was detected only in one case (2%).

Regarding the total number of complications during hospitalization, 17 (8.5%) patients had any one of the types of complications. No two or more types of complications occurred in one patient. The maximum number of complications (15 cases; 15%) was registered in group III. Moreover, blistering was the most frequent. In descending

order of frequency, necrosis of the wound edges ($n = 2$; 2%), superficial infection of the surgical site ($n = 1$; 1%), and rough postoperative scar ($n = 1$; 1%) were noted (Table 2).

Finally, we analyzed one of the important factors for the patient, that is, how comfortable the use of this wound dressing is for the patient. Despite the general satisfaction of the majority of the treated patients of all groups, 43 (43%) patients of group III noted maximum discomfort. In group I, there were 18 (36%) such patients, while 15 of them insisted on changing the existing dressing and switching to regular dressings with case follow-up of the wound by the attending physician. In group II, the number of patients who complained of bandage discomfort was the lowest, that is, 7 cases or 14% of the total number of the group. Statistical analysis when comparing all groups revealed a change in the coefficient from $p = 0.003$ to 0.048, which indicates significant differences.

Table 2

Postoperative complications in the studied groups

Complication	Patient group		
	I (n = 50)	II (n = 50)	III (n = 100)
Deep infection of the surgical site	0	0	0
Superficial infection of the surgical site	0	0	1 (1%)
Marginal skin necrosis	1 (2%)	0	2 (2%)
Rough postoperative scar	0	0	1 (1%)
Blistering	1 (2%)	0	11 (11%)
Bandage discomfort	18 (36%)*	7 (14%)	43 (43%)

*15 of 18 (30%) patients requested bandaging with the motivations "I want to see if everything is alright," "I would like to be bandaged like other patients."

Discussion

Surgical site infection occurs in 1%–2% of patients who underwent total knee arthroplasty [11, 12, 13]. According to a study of the causes that led to revision surgery after total arthroplasty, periprosthetic joint infection (PJI) accounts for 14.5% of the total number of revisions and 26.8% of the cases if the repeated intervention was performed within a year after primary arthroplasty [14]. One of the most important risk factors associated with PJI is postoperative wound infection [15, 16]. This makes the prevention of superficial wound complications one of the basic aspects of perioperative management of total arthroplasty [11]. One of the effective means is the use of modern dressing materials [17].

In the Proceedings of the Second International Conference on Musculoskeletal Infection, a separate section focused on a discussion of postoperative management of patients. During the discussion, a strong consensus was achieved, that is, occlusive and silver-impregnated dressings reduce the incidence of wound complications compared with standard gauze dressings. Moreover, dressings are recommended to be changed only when they get wet [18]. Although such a conclusion is essentially a compilation of expert opinion and does not have direct statistical support, it demonstrates the interest of orthopedic surgeons in this topic. Moreover, this interest has solely practical roots, namely, the minimum possible number of dressings and if they affect the course of the wound healing process in patients who underwent major orthopedic surgeries.

The general concept that formed the basis of our study can be formulated quite simply. We need to

find an effective wound dressing that can be a barrier to bacterial penetration, cope with excessive wound discharge, create an optimal environment for wound healing, and have an antibacterial effect [19]. To date, when discussing which dressing material best meets these requirements, the authors resort to evaluating various indicators, which can lead to difficulties in interpreting and comparing results [11]. This is possibly due to the fact that many of the criteria used to describe the condition of a postoperative wound are qualitative rather than quantitative, which makes their assessment too subjective. For example, to describe the impairment of skin integrity resulting from the use of a dressing, several terms are used in the literature, such as erythema, erosion, maceration, epidermal blisters, and blistering. Blistering is considered the most indicative and clinically significant. This term refers to the detachment of the epidermis from the underlying dermis, which is most likely caused by an increase in severe soft tissue edema in which the elasticity of the skin becomes insufficient. This may also be due to the low extensibility of traditional dressings, which leads to significant tension in the upper layers of the skin during movements in the operated joint [20].

Patient-related factors that increase the incidence of blistering include obesity, venous insufficiency, and diabetes mellitus [1]. Given that knee arthroplasty is often performed in older people with thin skin, the probability of this complication becomes even higher [21]; therefore, dressing change should be minimally traumatic. Clarke et al. evaluated the incidence of blistering with different types of dressings. In their study, this complication

occurred 19.5% less frequently with modern elastic bandages than with traditional ones [6]. This was also confirmed in our work.

In addition, problems with wound epithelialization can make it difficult to mobilize the patient, thereby increasing the duration of rehabilitation (both hospital and general). Obviously, postoperative wounds after total arthroplasty are located in the projection of the operated joints; accordingly, wound dressings should not restrict movement in them and should adapt to dynamic changes in the wound size so as not to affect adversely early postoperative rehabilitation [22]. This is also confirmed by Cosker et al. who revealed that inelastic dressings in combination with postoperative wound edema contributes to the occurrence of blistering and, moreover, is poorly tolerated by patients, causing unnecessary discomfort during rehabilitation [23]. In addition, adhesive interactive dressings provide a wide range of subjective benefits for the patient, including the ability to take a shower immediately after surgery [24, 25, 26].

Moreover, another subjective criterion is the amount of wound discharge, since there is no unified method for determining its redundancy. At a conference on the treatment of musculoskeletal infections, a consensus was reached that the more abundant and prolonged the wound discharge, the higher the probability of infectious complications [18]. Clarke et al. reported that adhesive dressings have effective absorption and retention of wound exudates, which reduced significantly the number of dressing changes [6]. In addition to the low frequency of blistering, other clinical advantages of this type of dressing material include a decrease in the average number of bed-days, fewer dressings during hospitalization, and no increase in the incidence of surgical site infection [23].

Another subjective criterion is the satisfaction of doctors, nurses, and patients. Each doctor and nurse evaluates the progress of the dressing, guided by personal experience and traditions of a particular department, which can vary greatly both between departments of the same clinic and between different hospitals. Individual patient satisfaction can also vary greatly, both in terms of assessing the pain syndrome associated with changing wound dressings and comfort during dressing or rehabilitation sessions [25].

The expediency of using dressings made using hydrofiber technology, impregnated with antiseptics, should be discussed separately. Does this enable restriction of the indications for the use of antibiotics? This is important in view of the presence

of hospital-acquired strains of multidrug-resistant microorganisms that cause surgical infection [27, 28]. Several modern researchers report improvement in the use of silver-containing dressings in the treatment of surgical wounds [29]. Silver ions have high antimicrobial activity against gram-positive and gram-negative flora, including antibiotic-resistant strains, and their use in modern wound dressings has significant potential advantages [27]. This can be scarcely overestimated, as Poultsides et al. showed in their study, conducted on the causes of surgical site infection in a hospital after primary hip and knee arthroplasty, that the total cost of treating such patients is approximately twice the cost of patients without this complication [30].

Kuo et al. revealed that the use of silver-containing dressing increased the period between dressings compared with the standard approach (5.2 ± 0.7 vs. 1.7 ± 0.4 days; $p < 0.0001$) and, accordingly, reduced the number of dressings (1.0 ± 0.2 vs. 3.6 ± 1.3 times; $p < 0.0001$). When using standard dressings, patients noted discomfort during their change and exercising with an exercise therapy instructor, which was not noted when using modern wound dressings. An increase in patient satisfaction with the bandage was registered ($p < 0.0001$) [25].

Chowdhry et al. reported the advantages of wound hydrofiber dressings compared with traditional dressings [31]. In this study, significant differences were found in the rate of subsidence of inflammatory phenomena in the group with contemporary dressings. This was manifested by a more pronounced dynamics of normalization of body temperature, a decrease in the level of leukocytes, and normalization of postoperative wound healing. Another study (56 patients) comparing traditional dressings with adhesive dressings showed a lower average number of dressings in the modern wound dressing group than in the passive dressing group (0.3 vs. 1.9 at $p < 0.001$) [32].

Nherera et al. indicated that the use of modern adhesive dressings is associated with fewer complications than traditional dressings [33].

Recent studies have shown that adhesive wound dressings reduce the number of dressings required, thereby reducing the cost of postoperative treatment, even taking into account their high cost compared with traditional materials [25]. Since dressings on a postoperative wound after arthroplasty are changed on average every other day, a decrease in the number of dressings reduces material costs, staff workload, and risk of wound contamination with pathogenic microorganisms [24].

Absorbent adhesive dressings are also not ideal, and one of the problems of orthopedists when using them is that the doctor cannot examine the wound within the next few days after surgery because of the dressing. In this case, dressing is performed either when the bandage is excessively wet, as was demonstrated in our study, or at the personal request of the doctor, which is not always justified. For several surgeons and patients, it was unordinary to examine the wound for the first time only 5–7 days after surgical treatment [8]. Therefore, it would be optimal if the wound dressing used after the surgery does not interfere with the wound examination and enable the assessment of paravulnar skin hyperemia and the identification of changes in local temperature, which is extremely important for diagnosing early infectious postoperative complications [17].

Thus, our data are consistent with those of current large studies and meta-analyses, suggesting that although modern dressings are more expensive than traditional ones, they may cause fewer skin complications (blistering). Moreover, their use reduces the hospitalization time, increases patient satisfaction with the treatment provided, and enhances satisfaction of doctors and nurses by reducing the number of complications and the comfort of using innovative wound care techniques. Furthermore, long-term multicenter prospective clinical studies are necessary to assess correctly both the economic efficiency and the role of modern wound dressings in the prevention of infectious complications.

Study limitations

This was a single center study with a small sample of patients. A multicenter analysis of the treatment of several thousand patients is necessary to assess adequately the influence of wound coverage factor on the risk of developing a deep surgical site infection.

Conclusions

In our study, the use of adsorbent sodium carboxymethyl cellulose dressings with silver ions did not affect the number of purulent-septic complications in patients and did not affect adversely the rehabilitation. In patients of both clinical groups, the range of motion in the knee joint at discharge and 3 months after surgery were not significantly different when using different types of wound dressings. Innovative dressings helped reduce the incidence of epidermal blisters in patients who underwent endoprosthesis replacement and reduce the number of dressings during hospitalization without negative consequences to the patient.

Disclaimers

Author contribution

Dmitrii V. Chugaev — the idea and design of the study, collection and processing of data, writing the draft.

Nikita S. Konovalchuk — the idea and design of the study, text editing.

Pavel G. Kogan — the collection and processing of data, text editing.

Nikolai N. Kornilov — text editing. *Evgenii P. Sorokin* — text editing.

Daniil N. Glaznyov — text editing.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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Ethics approval. Not applicable.

Consent for publication. Written consent was obtained from the patients for publication of relevant medical information and all of accompanying images within the manuscript.

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