COMPLICATIONS OF ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOGRAPHY: FROM PREVENTION TO MEDICAL MALPRACTICE

Thesis abstract

1. CONTENTS OF THESIS (ORIGINAL, ROMANIAN LANGUAGE)

2. GENERAL ASPECTS

As a highly complex interventional endoluminal technique with clinical - both diagnostic and mostly therapeutical utility -, endoscopic retrograde colangiopancreatography succeeded – along the latest five decades - in drawing a special interest from the part of the international community of researchers active in the field of digestive endoscopy.

The context approached in the present PhD research includes three main aspects, represented by: (i) the clinical domain of the complications produced by endoscopic retrograde cholangiopancreatography, (ii) the technological domain of the devices, appliances and biomedical softs, employed both for the procedure itself and in a connex manner, and (iii) the juridical, socio-professional and administrative domain, expected to assure a uniformly developed practice in relation to optimum terms of quality, cohesion and procedural feasibility. The common feature of these three domains is that of procedural safety, a concept that will be extensively developed and critically approached in the present study, starting from a detailed analysis of the present stage of the specific knowledge acquired in the three directions of interest, after which pertinent conclusions resulting from the analysis – based on the proofs obtained from six original investigations devoted to the three above-mentioned directions of research – will be drawn.

The Abstract of the PhD thesis also includes its full Content, with the corresponding paging. In a subsequent stage, a compact, synthetic selection of certain aspects characteristic to each direction of research was provided. The text also includes some of the most representative tables and figures – not all of them – illustrating the original work.

3. ASSESSING CAUSALITY FOR ERCP-RELATED ADVERSE EVENTS. A SINGLE CENTER PROSPECTIVE STUDY

3.1. Introduction

In latest years, endoscopic retrograde cholangiopancreatography, viewed as a therapeutical interventional method, brought about a complete change of the concepts describing the management of various hepato-billio-pancreatic diseases, the direct consequene being its increasingly invasive character and, implicitly, a more ample manifestation of the possible post-procedural adverse events (Blero et al., 2018).

If, traditionally, the ERCP used mainly for diagnostic purposes was generally characterized by increased risk of acute post-procedural pancreatitis, the higher complexity of the interventional manipulation gestures performed at the level of the biliary tract, pancreas or even the gall blader contributed to increasing both morbidity and adverse events, such as perforations, hemorrhage or post-ERCP infections. Accordingly, apart from this dynamics of the morbi-mortality parameters, caused by post-ERCP complications, recent socio-medical reality also evidenced an increased anxiety of patients, respectively the reserve of the professional staff confronted with ERCP, a situation with a direct impact, namely the high risk of medical malpraxis (Srinivasan et al., 2019).

3.2. Motivation and objectives

Considering the increasing interest manifested for the investigation of a possible causal relation between the experience acquired in centers of interventional endoscopy and the adverse post-ERCP events, a description – based on concrete proofs – of the multitude of elements with etiopathogenic nature regarding an intricate evolution observable at the level of a single center, appears as an absolute ”must”. If the total frequency of the procedures performed at central level was undoubtedly associated, through multivariate regression, with an inversely proportional ratio of the postprocedural adverse effects considered as a whole, as well as of the post-papillotomy hemorrhages considered separately, in cases of acute post-ERCP pancreatitis or of perforative events, this inverse correlation is viewed as hardly possible. Accordingly, performance indices – such as the mean duration of hospitalization and the total costs involved, patient’s satisfaction degree, the frequency of sequels on long term, or the necessity of a new intervention – are also followed.

3.3. Material și metode

Included in the study were 403 patients who benefited from a therapeutical CPRE at the ”Sf. Spiridon” County Clinical Emergency Hospital of Iași between 01.01.2018 – 31.08.2018. The patients were registered in a database elaborated in Microsoft Office, as an Excell Worksheet-type document. In relation with the parameters of personal and demographic identification, namely initials, personal identification code, age, sex, number of the observation sheet, the clinical section from which the patients came, respectively their social condition, were recorded. Patients' prospective monitorization included three stages: the preprocedural, the intraprocedural and the post-procedural one, respectively.

3.4. Rezultate și discuții

Within the batch under analysis, the weight of post-ERCP complications was of 19.1%, the most frequently observed being infection (8.93%), while pancreatitis was noticed in 8.68% of the cases; the clinically manifest hemorrhage (2.98%) and perforation (0.74%) attained a significantly lower ratio among post-ERCP complications.

The most frequent indication for endoscopic retrograde cholangio-pancreatography was coledocholithiasis, followed by the cholestasis syndrome and by the obstructive jaundice of uncertain etiology.

Complications were registered most frequently in cases of cholangiocarcinomas (43.6%) and in patients with chronic pancreatitis (33.3%). Among them, a significant association with the total presence of complications may be evidenced, by univariate analysis, only in cases of cholangiocarcinoma, and also by Bismuth anatomical subclassification for classes I and IIIrd.

For each type of complication, as well as for the presence of cumulated complications, a mathematical model for calculating the risk of post-CPRE complications occurrence was elaborated, starting from the pre- and intra-procedural parameters monitorized by the application of consecutive univariate and multivariate regression.

Overall survival of patients

Starting from the evolutive profile of patients and from the prospective monitorization of mortality in the first 60 post-ERCP days, the survival ratio was evaluated through Kaplan-Meier analysis along this period. The specific character of monitorization permitted to evidence the survival ratio over a 6 day interval, for the whole period considered (the moment of CPRE procedure – 60 post-ERCP days), as well as its recording

in a Life-Table with statistical significance. According to the analysis of the survival curves plotted in Figure 1, the survival ratio evaluated in the first 60 post-intervention days evidences a significant difference as a function of the total presence of post-ERCP complications (Log-Rank Test: LRT=4.102977, P= .00004).

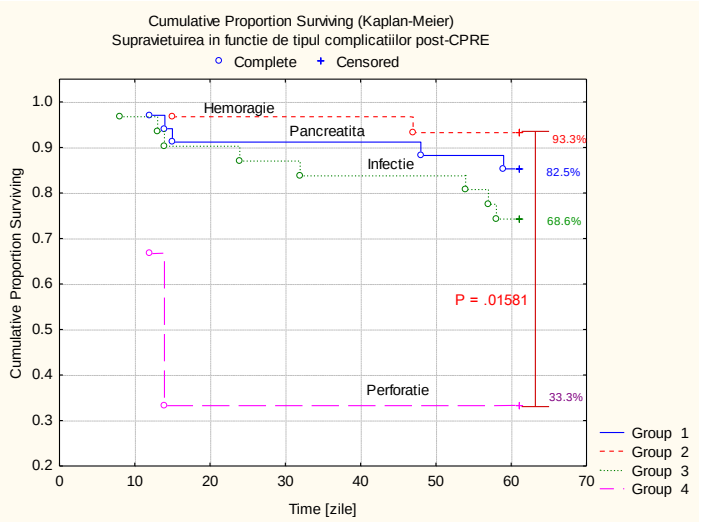

Figure 1. Kaplan Meier survival curves for post-CPRE adverse events

Post-ERCP pancreatitis

The present analysis aims at checking the correlations between the pre- and intra-ERCP parameters, on one side, and the installation of acute post-ERCP pancreatitis, on the other. The positive r correlation coefficients indicate a direct correlation, while the negative ones show a reverse correlation. A series of parameters, to be subsequently included in a system of prediction checking through analysis of the ROC curve, and then introduced in multivariate analysis, appears as having a statistically significant correlation level of univariate analysis. Both testing stages are discussed in the paragraph dedicated to the realization of the mathematical model of risk prediction.

The obtained results evidenced a significant and direct association between the pre-ERCP parameters, namely: indication of palliative nature, diagnostic of cholangiocarcinoma, Bismuth I class, diagnostic of vaterian ampuloma, previous exploration exclusively through CT, or the GGT levels, respectiveley the intra-ERCP parameters: type of duodenal papilla,

facile/difficult cannulation: cannulation attempts ≤5 vs. >5, cannulation time < 5 min vs. >5 min, unintended cannulation of the Wirsung duct, Needle Knife precut access sphincterotomy, Needle Knife transpancreatic papillotomy, or introduction of stents for billiar stenoses and acute post-ERCP pancreatitis. Univariate analysis also indicates parameters with reverse association, therefore with a possible protective capacity against acute post-ERCP pancreatitis, namely: the existence of a previous procedure (papilla with anterior sphincterotomy), the existence of billiar stents in situ, respectively the presence of billiary calculi.

Study of the extent of assocation between the pre- and intra- ERCP parameters with the post-ERCP complications may evidence some correlation among them, even if this association may be sometimes determined by certain interactions between variables (parameters vs. complications). In other words, sometimes, the observed association is not exclusively due to the relation between the two variables, but to the indirect intervention of other variables, defined as interactions, which modify the variable under analysis, so that, in a subsequent stage, it will apparently evidence a correlation with the complication under analysis.

The final objective of the study is to establish the predictive factors involved in the occurrence of post-ERCP complications, starting from a univariate association analysis, followed by checking of the predictibility degree of this parameter in the installation of complications.

Post-ERCP bleeding

In the study cohort, post-ERCP hemorrhage recorded a frequency of 2.98%, of which the mild forms represented 0.99%, moderate forms - 1.5%, and severe forms - 0.5%. In 1.24% of the cases, blood transfusion was necessary, the average number of transfused units being 2. Intra-procedural, non-clinically manifest hemorrhage occurred in 7.2% of the cases (29 patients). With the exception of 3 cases, all patients affected with clinically manifest post-ERCP hemorrhage also suffered from intraprocedural papillary bleeding, which was either spontaneously delivered or it was managed through an injection with adrenalin - 1/10,000 submucosly with the sphincterotome, for hemostasis attainment (according to the local protocol). Association of the pre- and intra-procedural parameters with the post-ERCP hemorrhage was analyzed through univariate analysis. Considering the reduced number of cases of post-ERCP hemorrhage, which means a small study sample, non-parametric tests specific to these types of statistical analyses were applied for univariate analysis of the correlations between the pre- and intra-procedural parameters.

The results obtained indicated no association of the pre-procedural parameters with post-ERCP hemorrhage. Significant associations with hemorrhagic complications were identified only for intra-ERCP parameters, as follows: difficult cannuling (tentative de cannuling trials ≤5/>5, and cannuling time 5min), cannuling of the Wirsung duct, presence of partial sphincterotomy, application of histological brushing with cytologic result of maligne type and absence of manoeuvres of endoscopic dilatation of the billiary paths. Considering the inferior statistical significance of univariate-type analysis, the parameters with significant association should be checked, through multivariate analysis, as to their independent and predictive character, in the development of post-ERCP hemorrhages. Multivariate analysis was integrated in the study performed for the generation of a mathematical model for calculating the risk of post-procedural hemorrhagic complications.

Post-ERCP infections

In the experimental group under study, infectious complications recorded the highest weight among the total number of adverse post-procedural events, with a frequency of 8.9%. An important aspect related to infectious complications is that they had been considered post-ERCP infectious complications, therefore including hepatic abscesses independent on the presence of cholangitis or cholecystitis, while, on the other hand, post-ERCP cholangitis equally included nosocomial cholangitis cases related to the duodenoscope and cholangitis with communitary character, strictly connected to the billio-obstructive pathology. Viewed on the whole, the most frequent infectious complication was cholangite (6.9%), followed by hepatic abscesses (1.5%), and by acute post-ERCP colecystitis (0.7%). Applying the same method of analysis employed for acute post-ERCP pancreatitis and post-ERCP hemorrhage, the association degree of the pre- and intra-procedural parameters, and the installation of post-ERCP infections were determined through univariate analysis.

The obtained results evidence a significant association between the occurrence of post-ERCP infection and the preprocedural parameters: the presence of stents in situ or of a previous ERCP procedure, of obstructive icterus, the diagnostic of cholangiocarcinoma, of acute cholangitis of ASA 3 and 4 class, of antibioprophylaxy, application of general anaesthesis (through oro-tracheal intubation), respectively the values of total bilirubine, of CRP and of leucocytes. A reverse correlation (therefore, with a potentially protective character) was registered between the establishment of diagnostics of choledoch lithiasis (especially of gallstones smaller than

1cm in diameter) or of cholestasis (type I SOD suspicion) and the occurrence of post-ERCP infections.

Post-ERCP perforations

In the experimental group here under analysis, three cases of post-CPRE perforation – representing 0.74% of all procedures – were identified. As a study of univariate correlation devoted to this type of postprocedural complications cannot be developed, the present section discussed in detail the evolutive clinical and paraclinical peculiarities of the three monitorized cases.

3.5. Conclusions

The prospective clinical study permitted the establishment of a risk profile for post-ERCP complications in patients requiring endoscopic billiopancreatic management in an emergency regional hospital. The successively identified risk circumstances, initially through univariate analysis, followed by a prediction study and multivariate analysis, were processed for the realization of a mathematical model for calculating the individual risk of each patient. Globally identified were, on one side, the traditional factors of risk for post-ERCP complications, and, on the other, the highly risky and predictive circumstances specific to the group under investigation. Among them, the diagnostic of cholangiocarcinoma as an indication for ERCP has s special causal significance, important especially in relation with the type of patients addressing the medical center here considered. Consequently, the patients with emergency recommendation for the management of billio-obstructive syndromes caused by maligne formations of the billiary paths should be recogized as an independent group of risk, if considering the defects associated to emergency addressing, which is a rather palliative aspect in oncological centers.

4. ERCP-RELATED MEDICAL LIABILITY. IDENTIFICATION OF RISK FACTORS FOR MALPRACTICE AND LITIGATION

4.1. Introduction

Since its introduction in endoscopic practice – initially in important medical centers, and then in numerous gastroenterology clinics – ERCP has represented an working technique covering a large range of interventions in the hepato-billiopancreatic domain, being applied, in 2013, with an average frequency of about 75 procedures per 100,000 patients in the United States of America (Yachimski et al., 2017). In this respect, ERCP supplies for a large ratio of both surgical billio-pancreatic interventions and percutaneous radio-interventional procedures, being nowadays applied in the management of almost all cases of common bile duct lithiasis (Maple et al., 2010), an aspect which exceeds by far the impact and visibility of this procedure in the public space. Concomitantly with this, increase of public perception on the peculiariaties of the interventional endoscopic procedures may appear as a threat, especially in relation with the potential adverse effects generating professional medical litigation (Cram et al., 2003).

4.2. Motivation and aims

The obvious and constant increase of the number of cholangiopancreatographic endoscopic procedures with therapeutical end, alongwith the substitution, through ERCP, of numerous complex surgical interventions, brings about modification of the risk-beneft ratio of such a procedure, by its increased degree of difficulty, respectively, of the level of severity in cases of post-procedural complications. More than that, the emergence of more and more medical centers with different levels of ERCP experience, in various societies, considered from the perspective of the litigation index, add to the non-uniform character of the litigation risk at global level. Up to now, with the exception of the highly visible cases, that aroused a special interest in the previously cited academic communities of the domain, the literary flux is lacking a systematic analysis of the ERCP-associated litigations. That is why, the need for coherent data of high statistical significance, referring to the premises, causes and possible risk factors, as well as to the solutions of the malpraxis cases associated to ERCP, is clear.

4.3. Methods

The objective of the present study is the development of a meta-analysis of the ERCP-associated professional litigations discussed in the

literature of the field, on the basis of certain preintra- şi post-procedural moderators. Accordingly, between 09.06.2017 – 27.09.2017, 11 databases of biomedical data have been accessed, as follows: EBSCO Academic Search Complete, Oxford Journals, Science Direct, Springer Link, ProQuest, Web of Science, Scopus, Wiley Journals, Taylor & Francis, Medline, Cochrane Library, respectively 4 databases with juridical character: Law Oxford Journals, ProQuest Criminal Justice, Emerald eJournals, Cambridge Journals. To define the cumulated effect, the Random Efect Model was employed, once known that individual analyses also assume, apart from the sampling error, factors which influence the effects. Equally, as the studies considered for meta-analysis report low frequencies, the Freeman-Tukey method was applied for compensating the erorrs of variability estimation in small sample groups.

4.4. Results and discussions

Meta-analysis evidenced that a correct establishment of ERCP recommendation, with the only exception of acute billiar pancreatitis, represents a protective, statistically significant factor for 214 malpraxis. In this respect, ERCP application in cases of billio-obstructive tumours shows the highest protection index. On the contrary, multivariate analysis evidenced that ERCP performed in cases of marginal indication because of abdominal pain, possibly of billiar origin, represents an independent risk factor for malpraxis, which may be identified, as well, trhough multivariate analysis. Also, the procedures indicated for acute billiar pancreatitis, even if correct, may induce an additional risk of malpraxis. Concomitantly with this, with the exception of post-ERCP hemorrhage, the whole series of post-procedural complications, even if in cases of patient's death, associate a high risk for litigation, the maximum risk parameters being specific to the decease caused by post-procedural perforation. As to the object of the judiciar request, the only aspect representing a risk factor for acknowledging medical malpraxis is the professional fault in post-ERCP monitorization and management. Surprisingly, formulation of the claim based on a faulty application of the ERCP technique appears as a protective factor in maintaining the medical malpraxis in an instance court. Mention should be here made of the fact that a decrease of the malpraxis cases of approximately 3%, yearly, a value statistically significant, was registered. The same tendency was also observed in cases of acute post-ERCP pancreatitis, its frequency vs the total number of malpraxis cases being reduced with approximately 2% yearly, again a statistically significant value. On the contrary, in cases of nosocomial infections, meta-analysis evidenced an abrupt increase, of more than 4% annualy, in the frequency of

these complications, comparatively with the total number of malpraxis cases, a tendency registering the highest coefficient of statistical significance ($p<0.0001$).

4.5. Conclusions

The present study discusses the numeruas implications of risk management in CPRE cases upon the medical professional community. Identification of some objective parameters for malpraxis risk quantification specific to some aspects related to the procedure permits, on one side, implementation of certain specific prophylaxy measures – namely evaluation and management algorithms, and, on the other, an a priori prediction of the individual litigation risk of each procedure. In this respect, the involvement level of the team of interventional endoscopy, both in the general communication with the patient and especially during the discussion for obtaining his/her informed consent, may be modulated for minimizing the risk of litigation.

5. AUDIT ON THE PERCEPTION OF GASTROENTEROLOGISTS AND SURGEONS OVER THE ERCP-RELATED ADVERSE EVENTS. APPLICATION OF A NATION-WIDE QUESTIONNAIRE

5.1. Introduction

Considering the successive evolution stages both from the viewpoint of clinical practice and from the technological perspective of ERCP along its almost 50 years of application, while aware of its obvious, increasingly invasive nature, doctors' socio-professional perception has been naturally subjected to modifications (Sivak et al., 2006). The premises of possible divergencies referring to the socio-professional cohesion of ERCP may originate, on one side, from the invasive character, accompanied by important complications, comparatively with the other therapeutical endoscopic procedures, or, on the other side, from the reserve mainfested by the medical staff in assuming the a procedure known as having a high litigation risk as well as a considerable personal exposure to professional noxes (Yachimski et al., 2017). At psycho-socio-professional level, the reverse of this evolution direction is the emergence of professional stress, of the burnout syndrome, of the reserve against an active professional involvement, or of the fear of professional litigations and malpraxis (Keswani et al., 2011, Niv et al., 2011, Vance et al., 2018, Cotton et al., 2019).

5.2. Motivation and aims

Sociological investigation and social intervention in medical groups represent quite new practices, yet with impact upon numerous specialities or multi- and transdisciplinary groups. Among the modern topics of research and social intervention, most frequently approached are doctors' overstress and burnout, migration of the labour force in the sanitary domain, the impact of socialization media upon medical activities, or the theme of sexism in medicine. In physicians, the anxiety induced by procedural complications and malpraxis risk may determine them to avoid a conduct with psycho-social and even juridical impact. The objectives of sociological research aims at establishing the frequency of respondents' contact with the patients in need of ERCP, a correct evaluation of the procedural indications, testing of respondents'perception on the possible adverse events and, last but not least, investigation of the main aspects related to professional training in the field of ERCP.

5.3. Methods

For evaluating the socio-professional and juridical implications of the ERCP procedure, a questionnaire including 23 items was proposed. Being a new questionnaire, its validation was necessary. Along the whole study, it was applied as a standardized instrument in relation with three methodological aspects: content, application and interpretation. Accordingly, the section devoted to the methods of investigation aimed, on one side, at validating and, on the other, at assuring the standard character of the intervention. Included in the study were 101 physicians, of whom 33 – specialized in general surgery and 69 – specialists in gastroenterology. The finalization ratio of the questionnaire among the subjects who accessed the web page was 80.5%. In the case of gastroenterologists, a relatively high ratio, of 37.7%, was registered for the respondents (26 physicians) who declared that the ERCP procedure is part of their current practice, while 62.3% of the subjects (43 physicians) declared that they do not practise ERCP on a daily basis.

5.4. Results and discussions

The question referring to the control of ERCP recommendation showed that the tendency of surgeons was only secondary to the importance of the diagnostic resources in billio-obstructive and pancreatic pathology. Consequently, referring strictly to acute billiar pancreatitis, most of the surgeons (over 40%) adopted the traditional management recommendations directly through ERCP, only about 37% of them opting for a more subtle positive diagnostic established by imagistic methods, the difference being statistically significant in the group under study.

The gastroenterologists for whom ERCP is a common practice represented a sociologically homogenous group, both by their considerable involvement in filling in the questionnaire, and by the tendency of response to the items of the interview they illustrated. Most of these specialists practise this procedure daily, while almost 70% of them solve, on the average, even 2 cases a day, which shows that, in Romania, the ERCP practice is polarized in Romania around the important medical centers, the tendency observed being based on statistically significant results.

Endoscopists face patients' insatisfaction in more than 60% of cases - weekly or monthly, an aspect with statistical significance, which may be correlated to a high risk of professional litigation. The generally positive impact of the implementation of some complex therapeutical procedures in interventional endoscopy is equally experienced by non-interventionist endoscopists, more than 80% of them (P=.007) asserting that they intended to practise ERCP on a daily basis in their professional career.

In support of this option, about 40% of the respondents practised ERCP in a certain moment of their carrer, after which – from various reasons – they gave up this procedure.

5.5. Conclusions

Nowadays, both gastroenterologists and generalist surgeons face the more and more acute issue of medical malpraxis implications in their daily professional practice. Cumulated aspects, such as professional stress, the burnout syndrome or over-crowding of the sanitary units contribute decisively to the increase of the general risk of malpraxis and litigations associated to medical care. ERCP practice in Romania is firstly characterized by simultaneous professional responsibilities, derived from the high probability that the same patient is managed by at least two specialists illustrating different medical profiles. The results of the sociological study illustrate beyond any doubt possible divergent opinions at interdisciplinary level, which may lead to disparities in medical assistance and, consequently, an increased litigation risk.

6. THE IMPACT OF DUODENOSCOPE MANUFACTURE MATERIALS OVER THE DUODENOSCOPE RELATED NOSOCOMIAL INFECTIONS. AN EXPERIMENTAL STUDY

6.1. Introduction

The issue of nosocomial infections associated with ERCP is not a new one, the first such case being described in the literature more than 30 years ago by Allen et al. because of a duodenoscope and ERCP. Due to the scale and impact that have characterized it in the last five years, this aspect has led to a re-evaluation of reprocessing standards and methods of controlling nosocomial infections related to interventional endoscopy globally (Calderwood et al., 2018), and consequently to the increase of the flow of the research projects regarding the possible causes of these infections.

In particular, multidrug-resistant microorganisms such as carbapenem-resistant Enterobacteriaceae strains have been associated with the emergence of ERCP-related nosocomial clusters, the main cause being the difficulty in reprocessing duodenoscopes, particularly the elevator canal (Rutala et al., 2015), independently of the potential lapses from standard duodenoscope reprocessing cycles (Epstein et al., 2014; Verfaille et al., 2015).

6.2. Motivation and aims

Duodenoscopes have been widely used for both diagnostic and therapeutic ERCP procedures, but recently, numerous outbreaks of multidrug-resistant organisms (MDRO) infections have been reported which has led to extensive research for their possible causes. Consequently, the aim of this study is to search for possible duodenoscope surface damages that could provide an alternative and plausible source of infections.

6.3. Methods

In order to assess both outer and inner surfaces, a duodenoscope was dismantled and samples were taken from the outer resin polymer and from the air/water, elevator, and working (biopsy) channels that were characterized by FTIR, DSC, TGA, AFM, SEM techniques and the antimicrobial activity were tested.

6.4. Rezultate și discuții

Alterations were noticed on both the coating and working channel polymers, with external alterations increasing progressively from the

proximal sample to the distal sample near the tip of the scope. However, as seen in Figure number 2, the results showed that the coating surface was still efcient against bacterial adhesion. Changes in surface texture and also morphological changes were shown.

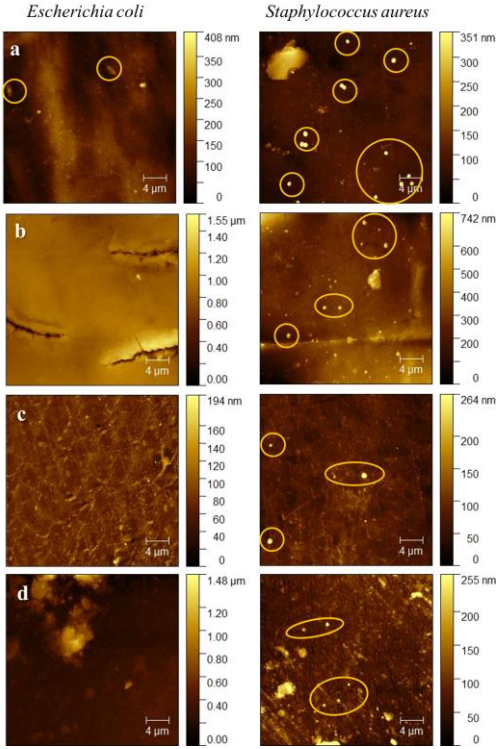

Figura 2. Topographyc AFM imaging of the four (a-d) selected specimes after innoculation with Escherichia coli and Staphilococcus aureus

6.5. Conclusions

The study describes the impact of routine procedural use and reprocessing cycles on the duodenoscope, showing that these may possibly make it susceptible to bacterial contamination and MDRO biofilm formation due to difficult reprocessing of the altered surfaces.

7. A POTENTIAL ALTERNATIVE FOR DUODENOSCOPE REPROCESSING BY PLASMA ACTIVATED WATER. AN EXPERIMENTAL STUDY

7.1. Introduction

The recent literature abounds in cases and series of cases related to nosocomial infections associated with duodenoscopy globally, and among the most commonly encountered pathogens, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Enterococcus faecalis*, *Escherseomia coli* and *Pseudomonas aeruginosa* (Kovaleva et al., 2013; Humphries et al., 2015), the common term in the pathophysiological process being their ability to form a multi-resistant biofilm adherent to surfaces and spaces that are difficult to access for reprocessing.

Regarding the manufacturers' recommendations on duodenoscope reprocessing, the standards of practice are aimed at either high-grade disinfection or sterilization (McDonnel et al., 2012; Kim et al., 2016), but ensuring that the standard of practice is achieved through the stepped reprocessing protocols drafted. by producers has been and continues to be questioned by many authors mainly due to the complex technological design and the many spaces that are difficult to access or even sealed within the structure of the duodenoscopes. In this sense, finding optimal alternative reprocessing solutions represents a constant direction of current research..

7.2. Motivation and aims

Plasma activated water (PAW) has been widely considered an effective agent for surface decontamination and is increasingly used for disinfection of medical equipment. The aim of this study was to evaluate whether the duodenoscopes currently on market are suited for the repeated use of PAWand to test the efficacy of PAW for their disinfection.

7.3. Methods

In order to evaluate the disinfection efficacy and the required time of contact, the duodenoscope samples were contaminated by immersing them in fasted-state simulated intestinal fluid containing Escherichia coli, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa*, prior to PAW exposure. In order to test the duodenoscope polymer compatibility with PAW, a challenge test was conducted by immersing the samples in PAW for 30 minutes daily for 45 consecutive days.

7.4. Results and discussions

Significant reductions in bacterial populations were achieved after 30 minutes of PAW treatment, indicating a high-level disinfection. Atomic force microscopy and scanning electron microscopy were used to demonstrate that repeated PAW treatment of duodenoscope coating polymer samples did not result in significant differences in morphological surface between the treated and untreated samples, as shown in Figure 3. Energy-dispersive X-ray spectroscopy analysis also showed no significant differences between the elemental composition of the duodenoscope coating polymer samples before and after repeated PAW treatment.

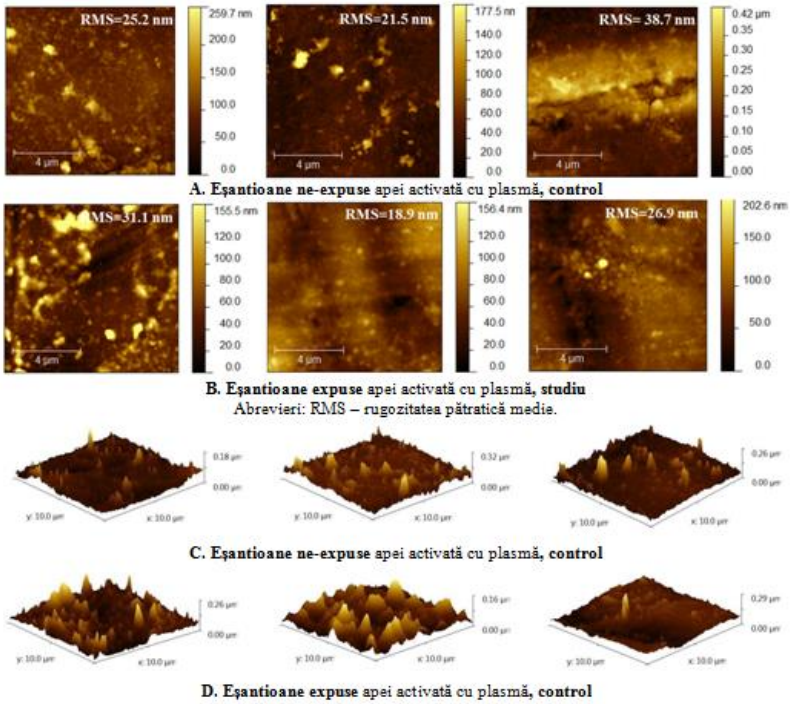

Figure 3. AFM evaluation of studied specimens before and after exposure to contamination and PAW

7.5. Conclusions

Considering these preliminary results, PAW could be considered as a new alternative for duodenoscope reprocessing.

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