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Original article

Compliance with antibiotic prophylaxis guidelines in surgery: Results of a targeted audit in a large-scale region-based French hospital network☆

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ABSTRACT

Introduction. – While regional monitoring of antibiotic use has decreased since 2011 by 3.2%, in some healthcare facilities a significant increase (+43%) has occurred. The purpose of this study was to assess regional antibiotic prophylaxis (ABP) compliance with national guidelines.
Material and methods. – In 2015, 26 healthcare facilities, both public and private, were requested to audit five items: utilization of antibiotic prophylaxis, the antimicrobial agent (the molecule) administered, time between injection and incision, initial dose, number of intraoperative and postoperative additional doses. Seven surgical procedures were selected for assessment: appendicectomy (APP), cataract (CAT), cesarean section (CES), colorectal cancer surgery (CCR), hysterectomy (HYS), total hip arthroplasty (THA) and transurethral resection of the prostate (TURP). A statistical analysis of the 2303 records included was carried out.
Results. – The general rate of antibiotic prophylaxis compliance was 64%. The antimicrobial agent used and initial dose were in compliance with the guidelines for 93% and 97.4% of cases respectively, and administration of antibiotic prophylaxis was achieved 60 minutes before incision in 77.6% of the records included. Regarding gastrointestinal surgery, amoxicillin/clavulanic acid was used in 32% of patients. In 26% of appendectomy files, administration occurred after incision, and one out of two files showed non-complaint perioperative and postoperative consumption.
Conclusion. – Compliance with nationwide ABP guidelines is in need of pronounced improvement, especially with regard to time interval between injection and incision and the molecule prescribed. An action plan based on specific recommendations addressed to each establishment and an updated regionwide ABP protocol are aimed at achieving better and reduced consumption of antimicrobial agents.

☆ Presentation in congresses: where do we stand with regard to surgical antibiotic prophylaxis (ABP)? Results of a regionwide study. Nicolas Prévost[a], Aurélie Gaultier[b], Julie Mocquard[a], Cécile Loonis[b], Gabriel Birgand[c], Aurélie Marquet[a], Jean-Claude Maupetit[a], Romain Dumont[d]. [a]OMEDIT Pays de la Loire; [b]Réseau Qualisanté; [c]Antenne régionale de lutte contre les infections nosocomiales (ARLIN) Pays de la Loire; [d]CHU de Nantes; congrès de la SFAR, septembre 2016, Paris, France. Évaluation régionale des pratiques d'antibioprophylaxie (ABP) chirurgicale/Regionwide evaluation of current practices in surgical antibiotic prophylaxis (ABP). F. d'Acremont[a], J. Mocquard[a], N. Prévost[a], A. Marquet[b], E. Batard[b], E. Rochais[a], J-C. Maupetit[a]. [a]Unité de coordination régionale, OMEDIT Pays de la Loire; [b]Observatoire des antibiotiques, OMEDIT Pays de la Loire; congrès Hopipharm, mai 2017, Nancy, France.

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1. Introduction

Notwithstanding indisputable advances in relevant preventive medicine over the last 20 years, surgical wound infections (SWI), known more broadly as surgical site infections (SSI), are still a major problem in public health. They represent 16% of healthcare-associated infections (HAI), placing them second (behind urinary infections) in terms of number of adverse events [1]. According to a recent analysis, approximately 800,000 SSIs occur yearly in Europe [2]. These complications lead to lengthening of hospital stay from an average 3.5 to 10 days, and per-patient treatment costs are multiplied by 3 [3–5].

The risk factors for SSI occurrence are associated with patients' individual characteristics (age, comorbidities. . .) and with operating conditions (emergency surgery, contamination class, duration of surgery. . .) [6]. Technical SSI preventive strategies have been detailed in recommendations of worldwide import [7,8]. Antibiotic prophylaxis (ABP) is one of the measures of which the impact has been the most precisely quantified in clean or clean-contaminated operations [9]. It is presently recognized that adequate ABP reduces SSI risk by approximately 50% [10]. The principles for its use have been clearly defined [9,11,12], and in France a single referential framework spells out the rules for ABP application in a surgical context [10,13]. And yet, notwithstanding these relatively simple recommendations, several studies have highlighted insufficient compliance [14–16]. In point of fact, failure to observe good ABP practices can have an impact that is not only individual, with the occurrence of postoperative infections, but also collective and environmental, in instances where misuse facilitates the emergence of bacterial resistance [4].

In a context marked by progressively increased antibiotic consumption, in a country that overconsumes with regard to the European average [17], antibiotic use in the health care establishments of our region has nonetheless tended to decline (−3,2% from 2011 to 2015). Conversely, it has tended to increase in small-scale (fewer than 100 beds) health care establishments (+43% from 2011 to 2015). It appears important to raise questions on the surgical role of antibiotic prophylaxis, which is problematically quantifiable, especially insofar as nationwide "quantitative" studies are primarily focused on antibiotic drugs. It is nonetheless possible to estimate antibiotic drug consumption in surgery units at 68.6 DDD/1000HD [18], given that on average, these entities prescribe 590.3DDD/1000HD, that is to say around 11% of antibiotic consumption in human medicine.

The objective of this study was to assess adherence in the health care establishments of our region to the nationwide good ABP practice guidelines issued in 2010 by the "Société française d'anesthésie et réanimation" (SFAR) [10]. This investigation represents the first step toward implementing an action plan aimed at improving the utilization of antibiotics during surgery.

2. Material and methods

2.1. Context and study design

A targeted retrospective clinical audit was conducted in 2015 based on the files of patients having undergone surgery between 1/01/2014 and 31/12/2014 in a surgical unit belonging to a network covering our region, which contains 117 health care establishments (approximately 12,000 beds), 41 of which are surgically active.

The audit was drawn up by a regionwide multidisciplinary expert group composed of anesthetists, pharmacists, hygienists and quality specialists. Whatever their status (public or private), the 41 medico-surgical establishments located within the region were contacted by e-mail via their antibiotic therapy point of contact and asked to participate in the audit.

2.2. Surgical wound/surgical site infection (SWI/SSI) prevention tracers

The surgical procedures targeted for auditing were identified on the basis of the following criteria: number of establishments implementing the procedure, procedure frequency in the establishments, existence of clearly defined ABP guidelines pertaining to the procedure and their inclusion in the Europe Path Project of the WHO (Performance Assessment Tool for Quality Improvement in Hospitals) [19]. In that context, in 2008 a retrospective tracer methodology audit analyzed four surgical procedures (total hip arthroplasty, colorectal cancer surgery, hysterectomy, coronary artery bypass surgery), the objective being to compare clinical practice with the nationwide recommendations. The methodology applied in our study is derived from this project. Three of the procedures analyzed in the 2008 audit (THP, hysterectomy and colorectal cancer surgery) were included in our audit, and our final selection was based on analysis of nationwide hospitalization data bases ("Agence technique de l'information sur l'hospitalisation").

The seven audited surgical procedures covered five surgical specialties:

- total hip arthroplasty (THA);
- cesareans;
- hysterectomy;
- appendicectomy;
- colorectal cancer (CCR) surgery;
- transurethral resection of the prostate by urethrocystoscopy (TURP) and;
- cataract surgery (Appendix I).

2.3. The study population

Among the seven procedures targeted for the study, the participating establishments preselected at least one operation in accordance with the criteria they had chosen. And then, by means of standardized random drawing using a tool devised by a regional expert group, each participating establishment selected 50 files for each procedure to be studied. In cases where, following application of the exclusion criteria, the number of files per procedure did not reach 50, exhaustive inclusion was requested. The following inclusion criteria were applied: age ≥ 18 years; surgery corresponding to one of the targeted procedures, hospital stay completed at the time of the audit.

The exclusion criteria for preselected files corresponded to patients with: previous operation during the three months preceding the targeted surgery, redo surgery for presumed sepsis, antibiotherapy during the operation, carriage or suspected carriage of *Staphylococcus aureus* resistant to methicillin (SARM, clinical specimen or positive screen test or hospitalization in intensive care, rehabilitation or long-stay centers), allergy to beta-lactam antibiotics, body mass index ≥ 35.

2.4. The data collected

Two types of data were collected. In the first place, a declaratory audit pertained to a given establishment's antibiotic prophylaxis policy, using an 11-item questionnaire drawn from the standard of best practices of the French Haute Autorité de santé [20] (Table 1). For each of the 11 criteria, a positive, negative or "to some extent" response was expected. The "to some extent" (partially) response corresponded to incomplete compliance with the questionnaire

Table 1
Indicators on institutional organization of antibiotic prophylaxis in the 26 establishments having undertaken the evaluation.

	Items taken into consideration	Yes, *n* (%)	Partially, *n* (%)	No, *n* (%)	NR, *n*
1	Single written ABP protocol for the entire establishment	19 (90%)	1 (5%)	1 (5%)	5
2	Protocol compliant with the updated recommendations (SFAR/ANSM)	18 (85%)	2 (10%)	1 (5%)	5
3	Protocol co-signed by surgeons and anesthetists	14 (67%)	3 (14%)	4 (19%)	5
4	Protocol having been presented to and validated by an institutional commission	20 (95%)	0 (0%)	1 (5%)	5
5	Frequency of updating and renewed validation of the defined protocol	12 (67%)	2 (10%)	7 (33%)	5
6	Defined frequency of updating and revalidation fully observed	12 (60%)	2 (10%)	6 (30%)	6
7	Protocol transmitted to all prescribers and other stakeholders	15 (75%)	4 (20%)	1 (5%)	6
8	Protocol submitted on arrival to new prescribers and stakeholders (*n* = 19)	11 (58%)	4 (21%)	4 (21%)	7
9	Protocol accessible at the sites of prescription and administration (*n* = 19)	19 (100%)	0 (0%)	0 (0%)	7
10	ABP prescription defined during anesthesia consultation (*n* = 20)	13 (65%)	6 (30%)	1 (5%)	6
11	Audit of ABP practices performed over the course of the last 5 years	20 (95%)	0 (0%)	1 (5%)	5

item and was considered as statistically associated with a negative response.

In the second place, the clinical audit was aimed at assessing current antibiotic prophylaxis practices. The following data were collected: patient age, antibiotic prophylaxis carried out (yes/no); if yes, date and time of the beginning and end of the operation, name of the molecule administered, route of administration, dosage, date and time of administration, duration of administration and number of reinjections (for each reinjection: name of the molecule, route of administration, date, time, dosage). These data were collected by the professionals in each establishment possessing expertise in antibiotherapy and having been designated when their establishments were selected.

2.5. The compliance analysis

Overall compliance with antibiotic prophylaxis practices was evaluated on the basis of an aggregate indicator composed of five items: performance of antibiotic prophylaxis, time of administration (time between injection and incision), molecule used, dosage and readministration according to the criteria detailed in Appendix II. It corresponds to number of patients presenting overall compliance regarding the five sub-indicators/total number of patients.

Detailed compliance for each item was evaluated according to waterfall methodology:

- utilization (ABP+ or ABP−) of antibiotic prophylaxis.
  Number of patients having received perioperative antibiotic prophylaxis/total number of patients;
- choice of molecule (antimicrobial agent) in the ABP+ files.
  Number of patients having received a molecule suited to type of surgical procedure/number of patients having received perioperative antibiotic prophylaxis;
- administration time (time between injection and incision) in the ABP+ files.
  Number of patients having received antibiotic prophylaxis in an adequate time interval (0–60 min)/number of patients having received perioperative antibiotic prophylaxis;
- choice of dose among the ABP+ files with a suitable molecule.
  Number of patients having initially received suitable dosing of antibiotic prophylaxis/number of patients having received a molecule suited to type of surgical procedure;
- time interval before readministration among the ABP+ files with a suitable molecule.
  Number of patients with a number of reinjections suited to the procedure/number of patients having initially received suitable dosing of antibiotic prophylaxis.

Postoperative antibiotic overconsumption is defined as one or more additional administrations following the end of the procedure, without signs of infection.

Absence of non-traceability was considered as non-compliance.

2.6. Statistical analyses

The regional expert group proceeded to a review of abnormal data found during collection and resubmitted them to the establishments, with a request for the return of subsequently modified files.

The indicators were calculated with a confidence interval set at 95%. The effects on the different indicators of a given establishment's size, status and activity volume were assessed. Descriptive analysis of the data was presented in percentages for categorical variables. Univariate analyses were conducted using Chi^2 tests, and 95% confidence intervals were calculated. Analyses were carried out using Stata release 10.0 software (Stata Corp LP, College Station, TX).

3. Results

Among the 41 contacted surgical establishments in the region, 26 (67%, including 2 university hospitals, 8 public hospital centers including 7 with more than 300 beds and 16 private establishments including 11 with more than 100 beds) were willing to participate in the audit. According to the medical information data center (PMSI), in 2013 they represented 83% of annual surgical unit stays within the region.

Following random draw and application of the exclusion criteria, 2303 (*n*) files were included in the analysis in accordance with the inclusion criteria of the study protocols. Total hip arthroplasty (THA) was the most frequently audited procedure (*n* = 663, 29% in 17 establishments), followed by colorectal cancer surgery (*n* = 406, 18% in 12 establishments), cataract (*n* = 300, 13% in 7 establishments), cesarean section (*n* = 279, 12% in 6 establishments), TURP (*n* = 258, 11% in 7 establishments) and, finally, hysterectomy (*n* = 159, 7% in 4 establishments) (Fig. 1).

3.1. The targeted clinical audit

The aggregate indicator of overall ABP compliance was satisfactory with regard to 64% of the procedures (*n* = 1477 out of *n* = 2303 files). It was highest for Caesarian section (91%), and lowest for appendicectomy (36%) (Table 2).

Detailed degrees of compliance for the five items evaluated are as follows (Fig. 2, Table 3):

- antibiotic prophylaxis was carried out in 95.2% (n_1 = 2192) of the procedures, ranging from 88% for cataracts (37 operations without antibiotic prophylaxis) to 99% for THA;
- among the procedures involving ABP (n_1 = 2192), the administered molecule was in agreement with the compliance criteria in

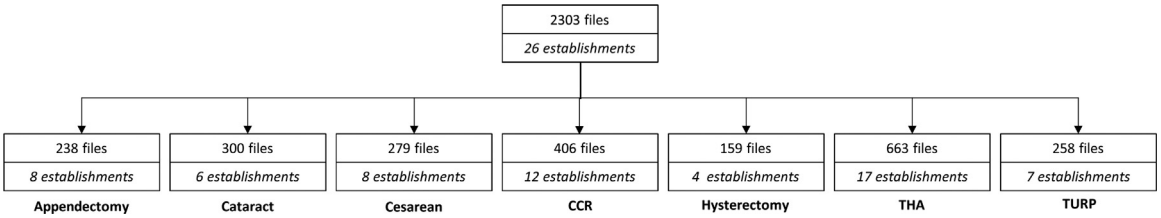

Fig. 1. Distribution of files included by procedures and by healthcare facilities.

Table 2
Aggregate indicator of overall compliance by procedure.

n = 2303	APP	CAT	CES	CCR	HYS	THA	TURP	Total
Numbers of files compliant as regards the 5 items								
Compliant antibiotic prophylaxis as regards molecule, time lapse between injection and incision, dosage and perioperative and postoperative reinjections	86	235	255	180	109	477	135	1477
Number of files evaluated	238	300	279	406	159	663	258	2303
Overall indicator	**36,1%**	**78.3%**	**91.4%**	**44.3%**	**68.5%**	**71,9%**	**52.3%**	**64.1%**

APP: appendicectomy; **CAT**: cataract; **CES**: cesarean; **CCR**: colorectal cancer surgery; **HYS**: hysterectomy; **THA**: total hip arthroplasty; **TURP**: transurethral resection of the prostate. The Overall indicator (bold characters) represent the compliance rate.

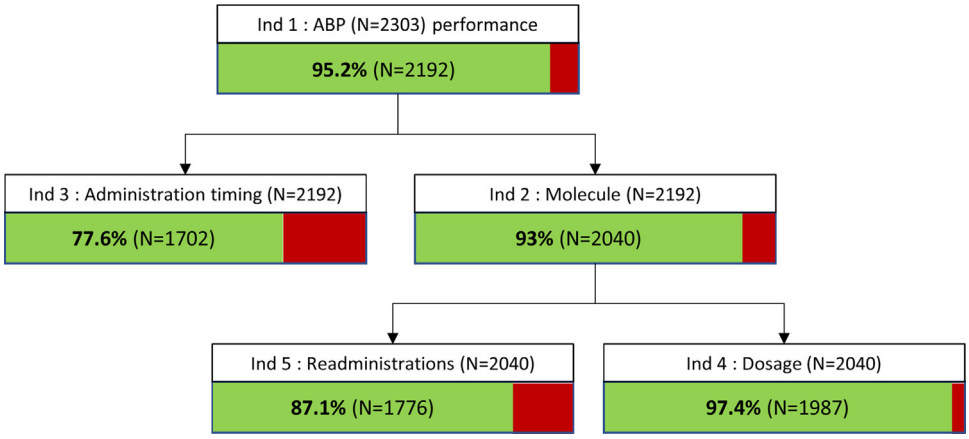

Fig. 2. Overall rate of compliance (by waterfall methodology) for all procedures.

93% of cases (n_2 = 2040), ranging from 82% (appendicectomies) to 100% (cataract);
- among the procedures with compliant administered molecule (n_2 = 2040), the dosing indicator was compliant in 97.4% of procedures (n_4 = 1987), ranging from 95% (appendicectomies) to 99% (caesareans, TURP),
- as regards readministration, overall compliance was 87.1% (n_5 = 1776), ranging from 60% (CCR) to 100% (caesareans);

- among the procedures involving ABP (n_1 = 2192), time between injection and incision (injection 0–60 minutes before incision) was compliant in 77.6% of the files (n_3 = 1702), ranging from 65% (appendicectomies) to 99% (caesareans).

While detailed statistical analysis of (overall and per item) compliance according to type of establishment (private/public, size, surgical activity) occurred, the results did not reveal significant differences between the establishments.

3.2. Focus on digestive surgery

As regards appendicectomies and colorectal cancer procedures, the aggregate compliance indicator presented rates lower than those recorded for the other operations. More precisely, in 26% of the files on appendicectomies involving ABP (56/216), injection took place after incision. Moreover, appendicectomies presented postoperative overconsumption in 20% (48/238) of the files (Table 4). And in 28% of the colorectal cancer procedures, the number of perioperative reinjections did not correspond to the compliance criteria, while 41.9% of operations lasting more than one hour did not involve a sufficient number of reinjections. One out of two CCT and APP files showed non-compliant overall perioperative or postoperative consumption (Fig. 3). What is more, according to the audited files, amoxicillin/clavulanic acid (32%) as ABP was used in considerable quantities in digestive surgery.

3.3. Organizational self-assessment: declaratory audit

All in all, 21 of the 26 participating establishments replied to the questionnaire investigating their ABP policies and practices. The majority of the establishments possessed protocols that were written (n = 19, 90%), validated (n = 20 95%) and accessible (n = 19, 90%) at the sites of prescription and administration. Frequency of revision and revalidation of the protocols was defined and observed in 12 establishments. The protocol was co-signed by surgeons and anesthetists in 14 (67%) establishments (Table 1).

Table 3
Compliance results by item and by surgical procedure in number and percentage.

Surgical procedure	n (n/n)	Antibiotic prophylaxis n_1 (n_1/n)	Molecule n_2 (n_2/n_1)	Time lapse n_3 (n_3/n_1)	Dosage n_4 (n_4/n_2)	Readministration n_5 (n_5/n_2)
Appendicectomy	238 (10%)	216 (91%)	177 (82%)	141 (65%)	169 (95%)	120 (68%)
Cataract	300 (13%)	263 (88%)	263 (100%)	253 (96%)	256 (97%)	252 (96%)
Cesarean	279 (12%)	270 (97%)	263 (97%)	257 (95%)	262 (99%)	263 (100%)
Colorectal cancer surgery	406 (18%)	400 (98%)	342 (85%)	321 (80%)	336 (98%)	205 (60%)
Hysterectomy	159 (7%)	154 (97%)	147 (95%)	121 (79%)	144 (98%)	139 (95%)
Total hip arthroplasty	663 (29%)	655 (99%)	642 (98%)	533 (81%)	615 (96%)	598 (93%)
Transurethral resection of the prostate	258 (11%)	234 (91%)	206 (88%)	159 (68%)	205 (99%)	199 (97%)
Total	***n* = 2303**	***n*$_1$ = 2192 (95,2%)**	***n*$_2$ = 2040 (93,0%)**	***n*$_3$ = 1785 (81,4%)**	***n*$_4$ = 1987 (97.4%)**	***n*$_5$ = 1776 (87.1%)**

n: number of files evaluated. n1: number of files compliants as regards utilization of antibiotic prophylaxis. n2: number of files compliant as regards utilization of antibiotic prophylaxis and choice of molecule. n3: numbers of files compliants as regards utilization of antibiotic prophylaxis, choice of molecule and administration time. n4: numbers of files compliants as regards utilization of antibiotic prophylaxis, choice of molecule and choice of dose. n5: numbers of files compliant as regards utilization of antibiotic prophylaxis, choice of molecule and readministration.

Table 4
Focus on appendicectomy (time between injection and incision, and postoperative antibiotic consumption).

APP	Compliant files on ABP application (item 1)	Compliant files on timing (item 3)	Non-compliant files on item 3			Compliant files on postoperative consumption	Postoperative overconsumption
n	n_1	n_3	Too early (>60 min)	Too late (after incision)	Not given		
238	**216**	**141**	**7**	**56**	**12**	**129**	**48**

n: number of files evaluated. n1: number of files compliants as regards utilization of antibiotic prophylaxis. n3 : numbers of files compliants as regards utilization of antibiotic prophylaxis, choice of molecule and administration time.

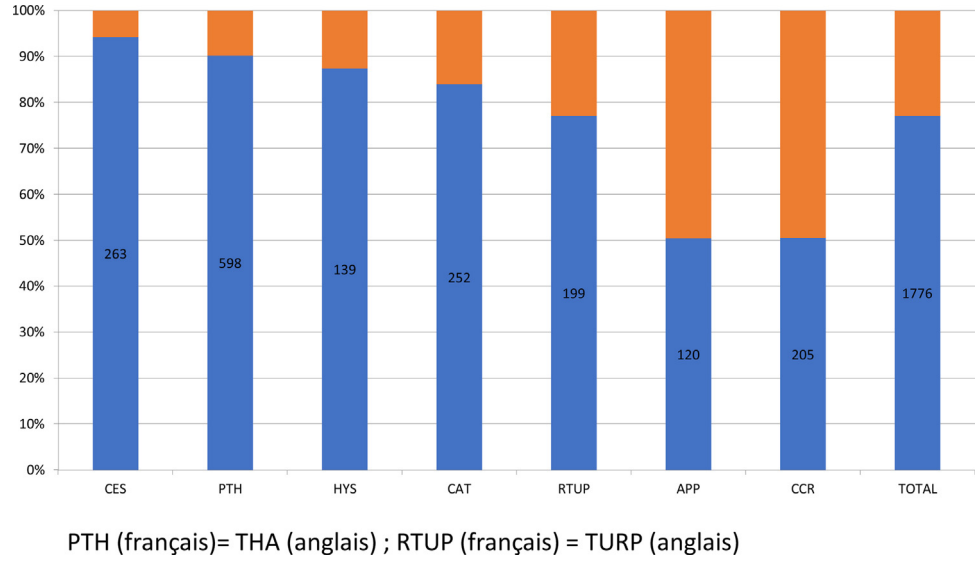

Fig. 3. Rate of compliance for additional doses (in blue) by procedure.

4. Discussion

Our work provided an opportunity to study a large multicenter population representative of different types of establishments in a major western France region (public/private, <100 beds, <300 beds, >300 beds) and including the most widely represented surgical specialties. Detailed analysis of the data collected specifically for this investigation distinguish this work from existing surveillance networks, highlighting overall ABP compliance in 64% of the files assessed. This result corresponds to the 0.3–84.5% scale detailed in the review carried out by Gouvea et al. [21], and compares favorably to the 9.4% compliance recorded in a study of more than 14,000 files in accordance with a methodology comparable to ours [22]. The compliance rates of 40, 53 and 67% reported in other French studies [15,23,24] at once underlines the coherence of our result and shows that practices still need improvement.

These data were partially compared to those collected during the implementation of World Health Organization's Performance Assessment Tool for Quality Improvement in Hospitals (PATH) project [19]. The French results in the framework of this project showed overall conformity of 52% for colorectal cancer surgery, 90% for the THA procedure and 59% for hysterectomy. The one significantly different divergency resided in choice of molecule during colorectal cancer surgery. Notwithstanding the apparent

discrepancy, our study does not show more satisfactory antibiotic prophylaxis compliance results on a local scale.

In its 2006 audit report on ABP in the operating theater in France, the HAS came to grips with ABP anomalies by raising the issue of heterogeneous health care practices in the different facilities [25]. The report underscores:

- a low number of caregiving protocols corresponding to the required quality criteria;
- protocols that are neither updated, nor co-signed;
- major disparity of perioperative prescriptions (dosing, administration, injection timing, reinjection. . .), and lack of traceability;
- inadequate circulation of SSI surveillance results (validated indicator of health care quality) amongst the concerned staff members.

Analysis of the declaratory audit showed that co-signature of the protocol by an anesthetist and a surgeon was lacking in 30% of the cases reported in our region and that updating issues were occasioned by difficulties in assigning a role to each professional involved in antibiotic prophylaxis. Indeed, organizational issues could complicate efforts to follow the recommendations, even though good surgical ABP practices are specified in protocols, most of which originate from single, well-known and widely accepted nationwide guidelines. However, standardization of practices in accordance with reference documents seems difficult to achieve; whether in France [15,23,26] or the rest of the world [14,16], the existence of guidelines does not suffice to standardize medical practices. While a pronounced reduction of SSIs, approximating 30%, was observed between 1999 and 2006 [27], the latest health monitoring reports show a slowing of the decline and even, in some surgical specialties (digestive surgery. . .) a resurgence of untoward events. While the reasons for this evolution seem indistinct and are under investigation, it appears evident that non-compliant ABP administration is a major risk factor for SSI, as has been amply demonstrated in the past [28–30]. According to Stulberg et al. (2010), only total overall compliance is significantly associated with decreased risk of SSI [31]; reinforced attention and rigor during ABP is consequently that much more vital.

One of the most problematic compliance criteria is time elapsed between injection and incision. Even though administration of prophylactic antibiotics prior to skin incision seems to be at once essential to ABP efficacy and relatively easy to carry out, compliance rates inferior to 50% have frequently been noted [21]. Indeed, non-compliance can be considered as the factor most pronouncedly associated with SSI occurrence [32,33], and respect for administration timing is a fundamental point upon which we have laid considerable emphasis. Once again according to Steinberg et al. and after their having excluded antibiotic prophylaxis by means of prolonged perfusion molecules such as vancomycin, SSI risk was 1.6% when the first dose was administered 30 to 0 minutes before incision (early administration), and 2.4% when the first dose was administered 60 to 31 minutes before incision (late administration) (non-significant difference with OR 1.74; 95%CI 0.98–3.04). Even though it is non-significant, this tendency justifies our compliance criterium, namely "injection of the first dose 60 to 0 minutes before incision" (Appendix II), and not in time intervals ranging from 60 to 30 minutes before incision, as recommended by the HAS methodology [20]. The new SFAR guidelines published in 2017 and updated in 2018 put an end to the exceptional status of Cesarean section by excluding umbilical cord clamping as a criterion for ABP timing determination and indicated that injection was to take place during the 30 minutes preceding incision [13]. While the definition of "time interval" has remained debatable (60–30 minutes vs. <30 minutes before incision [34,35]), what remains essential is the imperative need to administer antibiotic prophylaxis prior to incision.

In 2016, official monitoring of SSI led to the conclusion that SSI incidence in digestive surgery was significantly higher for procedures in which ABP application was not in compliance with the SFAR guidelines (OR = 2.24, CI 95% = [1.27–3.97], $P < 0.01$) [36]. Reported instances of non-compliance were due mainly to:

- non-observance of the recommended time interval between injection and incision and to;
- choice of a non-recommended molecule.

In our regional study, rate of compliance with the recommendations for use of each molecule was evaluated (Appendix II). However, the resulting correlation was not found in the results published the year after [36].

The difference between our study and these results resided in more frequent utilization of amoxicillin/clavulanic acid in our region than in France taken as a whole (48% vs. 41% in 2016, data unavailable in 2017). In digestive surgery, amoxicillin/clavulanic acid association was among the operative nationwide recommendations at the time of the study, during which its application was deemed compliant. However, the association was contradictory to one of the basic principles put forward in the same recommendations (on the use of antibiotics in ABP), namely that curative molecules should not be used in prophylaxis. In the above-mentioned context, the association may consequently be considered as non-optimal.

The above observations on the importance of choice of molecule and compliance with timing confirm the need to improve ABP practices, particularly in digestive surgery, and to address relevant organizational questions. For example, the planned or unplanned nature of an operation is liable to have an impact on degree of compliance with timing, as is illustrated during major appendicectomy by a higher number of injections after incision than at least 60 minutes before incision. So much said, this result cannot be generalized to the other procedures analyzable by tracer methodology.

The limitations of this clinical audit consist in the biases related to:

- the heterogeneity of data collection tools and;
- the variable exhaustiveness of the patient files from one facility to the next.

In Our working group proceeded to critical rereading of the results of each establishment in view of revealing potential anomalies in data capture and inclusion, the objective being to facilitate correction and improvement of data quality. The fact that the files were directly forwarded by auditors from the hospitals may have generated:

- selection bias with regard to the audited procedures and;
- volunteer selection bias by the professionals (choice of procedures, choice of files. . .) who may have been responding to regional or institutional exigencies in terms of either assessment or results.

On the field, several identifiable lines of improvement can be integrated in an antibiotic stewardship approach [37], which may be defined as any program for management of antimicrobial use aimed at monitoring antibiotic consumption and optimizing antibiotic utilization, the objective being to prevent the emergence of resistances without compromising patient safety. Here are some suggestions, some of which already have been or are being put into practice:

- prescription of the ABP blueprint during the preoperative anesthesia consultation, thereby allowing injection of the patient on arrival in the operating theater, within the hour preceding incision;
- systematic compliance prior to incision with the "antibiotic prophylaxis" item (see Table 3) and of optimized injection timing during the final preoperative verification in the operating theater. On this point, the checklist item in the most recent (2018) HAS recommendations entitled "patient safety in the operating theater" ("Antibiotic prophylaxis has been carried out in accordance with the recommendations and protocols in force in the establishment") could be rendered more explicit with regard to optimal time interval between injection and incision. Even though its efficacy remains debatable, this compliance criterium is common to almost all surgical procedures [38,39];
- a regionwide protocol complying with the updated nationwide recommendations and privileging antibiotics that do not generate resistances, has been drawn up and disseminated at the regional level;
- an approach aimed at promoting multidisciplinary exchanges amongst region-based practitioners (anesthetists and surgeons in particular), the objective being to identify organizational obstacles and to establish cause-and-effect relationships between specific difficulties and precise instances of non-compliance;
- a regionwide synthesis indicating identified lines of improvement and conveying key messages has been drawn up and disseminated;
- an establishment-based synthesis identifying lines of improvement specific to each establishment and comparing that establishment's results with those of others in the region has been transmitted to each one of them.

In parallel, by excluding a clavulanic acid/amoxicillin association during antibiotic prophylaxis in digestive surgery, the 2018 updating of the SFAR recommendations confirmed the need to choose alternative solutions not used in curative antibiotherapy.

5. Conclusion

This targeted clinical audit conducted within a large-scale network of establishments with surgical activities showed a need for improvement in observance of ABP recommendations, especially in terms of injection time, molecule prescribed and incision time.

An action plan has been put into place, the objective being to upgrade prevention of postoperative infections while limiting antibiotic consumption on a regionwide scale, particularly as regards antimicrobial agents with a pronounced ecological impact and of which the spectrum permits their curative use. Impact assessment will be part and parcel of a new clinical audit, which will once again be dedicated to continued improvement of current practices. Last but not least, reflection on organizational, environmental, human and managerial factors appears essential to identification of obstacles to enhanced practice of antibiotic prophylaxis in the operating theater.

Contribution of authors

NP participated in drafting the protocol, collected data, analyzed the results and participated in the writing of the article.

AG carried out the statistical analysis.

GB, RD and ER participated in drafting the protocol, in criticizing the results and in writing the article.

NT participated in the statistical analysis, in drafting the article, in criticizing the results and in writing the article.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix I. CCAM taken into account for each application of tracer methodology

Tracer procedure	CCAM codes
Planned total hip arthroplasty	NEKA020, NEKA012, NEKA014, NEKA011, NEKA010 NEKA016, NEKA017, NEKA021, NEKA015, NEKA013, NEKA019
Cesarean	JQGA002, JQGA003, JQGA004
Hysterectomy	JKFC002, JKFC005, JKFA015, JKFA018, JKFA024, JKFA026 JKFC003, JKFA002, JKFA025, JKFA028
Transurethral resection of the prostate	JGFA015
Cataract	BFGA004
Appendicectomy	HHFA001, HHFA011, HHFA016
Colorectal cancer surgery	CCAM codes for colonic cancer to be combined with the diagnostic code C18* : HHFA009, HHFA008, HHFA018, HHFA023, HHFA014, HHFA017, HHFA010, HHFA024, HHFA006, HHFA002, HHFA021, HHFA005, HHFA022, HHFA004

Appendix II. Antibiotic prophylaxis compliance assessed by tracer methodology, based on the SFAR 2010 guidelines

Surgical procedure	Molecule	Dosage	Time of administration	Perioperative readministration(s)	Postoperative readministration(s)	Recommendation source
Appendicectomy	Cefoxitin *or* penicillin A and beta-lactamase inhibitor *or* CIG/CIIG and imidazole	2 g	0–60 minutes before incision*	1 g if > 2 h	Limited to perioperative period	SFAR [10]
Cataract	Intracameral cefuroxime	1 mg	End of operation	Single dose	Limited to perioperative period	AFSSAPS
Caesarean	Cefazoline *or* Cefamandole *or* Cefuroxime	2 g *or* 1.5 g *or* 1.5 g	Perioperative	Single dose	Limited to perioperative period	SFAR [10]
Colorectal cancer surgery	Cefoxitin *or* penicillin A and beta-lactamase inhibitor *or* CIG/CIIG and imidazole	2 g	0–60 minutes before incision*	1 g if > 2 h	Limited to perioperative period	SFAR [10]
Hysterectomy	Cefazoline *or* Cefamandole *or* Cefuroxime	2 g *or* 1.5 g *or* 1.5 g	0–60 minutes before incision*	1 g if > 4 h *or* 0.75 g if > 2 h *or* 0.75 g if > 2 h	Limited to perioperative period	SFAR [10]
Total hip arthroplasty	Cefazoline *or* Cefamandole *or* Cefuroxime	2 g *or* 1.5 g *or* 1.5 g	0–60 minutes before incision*	1 g if > 4 h *or* 0.75 g if > 2 h *or* 0.75 g if > 2 h	Up to 24 h	SFAR [10]
Transurethral resection of the prostate	Cefazoline *or* Cefamandole *or* Cefuroxime	2 g *or* 1.5 g *or* 1.5 g	0–60 minutes before incision*	1 g if > 4 h *or* 0.75 g if > 2 h *or* 0.75 g if > 2 h	Limited to perioperative period	SFAR [10]

*Compliance in timing of administration was defined by the expert group having proposed the evaluation of professional practices (EP), and it differs slightly from the SFAR 2010 guidelines (cf. discussion).

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