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RESEARCH

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Impact of two-level filtering organization on population's accessibility to an emergency medical communication centre

Lydie Uro¹, Yann Penverne², Henri Delelis-Fanien³, Louis Soulat¹, Joel Jenvrin² and Paul-Georges Reuter^{1,4*}

Abstract

Background Emergency Medical Communication Centres (EMCCs) play a critical role in the timely coordination of out-of-hospital emergency responses. As demand for emergency services continues to rise, these centres face significant challenges in maintaining operational efficiency and service quality in order to provide a priority response to life-threatening emergencies. While the two-level answering system – i.e. a two-tiered response by call takers – has shown promise in simulation studies, its effectiveness in real-world settings has yet to be fully evaluated.

Objective This study aimed to assess the impact of implementing a two-level answering system on service quality (rate of answered calls) at 30 s (QS30) across three EMCCs, marking the first evaluation of this system in everyday operations. We also investigated how variations in organizational structure among the EMCCs may influence QS30.

Methods We conducted a multicentric, observational, retrospective study analyzing call data collected between May and June of 2022 and 2023, in France. Three EMCCs—35, 44, and 86—were included, with EMCCs 35 and 44 having implemented the two-level system, while EMCC 86 served as the control. Each EMCC employed distinct organizational models for the two-level system. Key performance indicators were assessed using non-parametric statistical tests, including the Wilcoxon and Kruskal-Wallis tests. Additionally, structural equation modeling was used to explore relationships between variables affecting service quality.

Results A total of 255,438 calls were analyzed, with 152,108 calls during the two-level period. The QS30 for EMCC 35 ranged from 93% in 2022 to 91% in 2023 ($p < 1e-4$), while EMCC 44 saw an increase from 91 to 100% ($p < 1e-4$). In contrast, EMCC 86 maintained a stable QS30 of 100%, with no significant change in activity ($p = 0.1$). Further analysis revealed significant differences in QS30 across the three EMCCs, suggesting that the distinct organizational structures of the two-level systems influence overall service quality. Structural equation modeling also highlighted strong correlations between call volume, agent workload, and QS30, emphasizing the impact of staffing and organizational structure on service quality.

Conclusion The findings suggest that the two-level answering system may be effective in enhancing EMCC performance, particularly in managing increased call volumes. Additionally, the study highlights the potential

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importance of organizational differences in shaping QS30 outcomes. Future research should focus on longitudinal effects and explore innovative strategies to sustain high-quality EMCCs amidst evolving demands.

Keywords Emergency medical communication centres, Two-level answering system, Service quality, Emergency response, Call volume, Organizational structure

Introduction

Emergency Medical Communication Centres (EMCC) are essential in receiving and coordinating out-of-hospital emergency requests. These centres ensure a rapid and appropriate response to critical situations. However, they face a continuous annual increase in demand [1, 2]. This trend presents significant challenges for EMCCs, particularly regarding the assessment of situation severity and response times. Accurate assessment is vital for optimizing resource allocation, which is crucial for improving the survival rates of the most critically ill patients [3–5]. Meanwhile, timely responses directly impact service accessibility for the population.

Recommendations for managing emergency calls vary widely across countries, depending on their healthcare organization and care systems. Nevertheless, they all share the common goal of reducing response times. This objective is measured by the quality of service (QS), defined as the proportion of calls answered within a specified timeframe. Accessibility is influenced by various factors, including the volume of incoming calls, the workload of staff, and the characteristics of individual centres [6]. In France, the service can be accessed via a single telephone number, available 24/7 throughout the country [7]. Calls are initially answered by a call taker, who collects information regarding the reason for the call, as well as the identity and location of the caller, before transferring the case to a regulatory physician. Every call must be managed or supervised by a physician, who may be either an emergency physician working in a hospital or a general practitioner primarily operating in private practice [7, 8].

Improving accessibility is a major challenge. Given that human resources cannot be indefinitely expanded, optimizing response capabilities is essential. The implementation of a two-level answering system is one proposed solution. During the COVID crisis, there was a significant surge in calls [9]. The introduction of the two-level system has proven to enhance accessibility [10]. Simulation studies support the effectiveness of this approach in daily operations [11–15]. France is evolving the organization of EMCCs towards a new model that fosters collaboration between urban and hospital settings. This partnership is exemplified by the establishment of a call regulation platform, accessible 24/7, integrating two sectors: on one hand, the medical regulation of emergency medical assistance, and on the other, general medicine regulation during the day for non-scheduled care. This latter

component is managed by both liberal regulatory physicians and non-scheduled care operators (NSCOs). Their role includes securing general medicine appointments within 48 h for patients whose need for non-scheduled care has been confirmed by the regulatory physician. The two-level system is recommended for use. A first-level call taker (CT-N1) answers and identifies the reason for the call. In cases of life-threatening emergencies, they have the authority to dispatch operational resources (BLS or ALS rescue teams) and engage directly with the emergency physician. In other cases, a second-level call taker (CT-N2) takes over to continue the call assessment and direct it to either urgent care (UC) or non-scheduled care (NSC) pathways.

While modelling studies affirm the necessity of implementing the two-level system, various modalities for its application are possible, and no research has yet compared their practical effectiveness. This study aims to assess the accessibility of the population based on different organizations of two-level filtering in real-world conditions.

Methods

Study design

We conducted a multicentric, national, observational, retrospective and comparative before-after study on the organisation of the French healthcare systems.

The introduction of two-level systems did not take place in the same way or at the same rhythm everywhere in France. Three sites, which had already at least partly implemented it, were identified for collecting data: EMCC 35, 44 and 86. They were in metropolitan France and had the same advanced telephony system (CC Pulse, etc.), enabling standardised data extraction.

The inclusion criteria concerned all calls received by an EMCC answered by a CT-N1, whatever their origin (public, family doctor, homecare nurse, etc.). The non-inclusion criteria were calls received by an EMCC not picked up by a CT-N1, such as reports transmitted by the fire brigade or ambulance services, emergency medical services teams in intervention, or call transfers from fire brigade or police call platforms.

The inclusion periods were May and June of 2022 and 2023.

The study protocol was validated by the Rennes University Hospital Ethics Committee on November 14th, 2023. The trial adhered to the principles of the Declaration of Helsinki.

Description of these EMCC activities

Each of the three centres participating in the study had implemented a different version of a two-level pick-up system. These operating modes differed in each centre and are presented in detail below.

In 2023, EMCC 35 and 44 had implemented the two-level mode. So, 2023 period was compared with 2022 period. EMCC 86 served as a control centre because the transition was made before 2022.

Operational description of the three EMCCs in the study, is presented in the [Appendix](#).

EMCC 35 is implemented in the city of Rennes. It operated a two-level service with a maximum range between 8am and 11.59pm 7 days a week, but not yet systematically between 8pm and midnight. The CT-N2 consisted solely of NSCOs. Referral to the emergency physician was made directly from the CT-N1, which had handled the call from start to finish before transfer. For call takers, call distribution was automatic, and the call was picked up manually.

EMCC 44 is implemented in the city of Nantes. It operated on a two-level basis. The two-level hours varied according to the number of staff and all the periods were clearly identified on the telephony software. The call takers were CT-N1, CT-N2 UC and CT-N2 NSC. The NSCOs had the role of CT-N4, i.e. referring the patient once the medical decision had been made. The system worked as follows: the CT-N1 picked up the phone, looked for a life-threatening emergency and, if necessary, treated it; if this was not the case, the patient was transferred to the CT-N2, depending on the type of emergency.

EMCC 86 is implemented in the city of Poitiers. It operated on a two-level 24-hour a day. During the day from 7.30am to 7.30pm: 2 CT-N1, 2 CT-N2, and 1 CT coordinating call takers (involved in taking N1 or N2 calls depending on the flow, in a flexible way). From 8 a.m. to 8 p.m., a line of NSCOs, who were involved in CT-N2 calls that came under the responsibility of general practitioners. In the evening from 7.30pm to 7.30am: 1 CT-N1 and 2 CT-N2. The CT-N2s also helped the CT-N1 if there were calls waiting in the room. Automatic pick-up was only available on CT-N1.

Variables collected

The telephony data were collected on an hour-by-hour basis.

The names and descriptions of the variables extracted for the three participating centres were as follows: centre: identification number of the centre, corresponding to the INSEE code of administrative department, date (dd/mm/yy): date of the day of the time slot concerned, hour (integer between 0 and 23): hour of the time slot concerned, incoming (integer): number of incoming calls in the

time slot concerned, answered (integer): number of calls answered in the time slot concerned, outgoing (integer): number of outgoing calls in the time slot concerned, time (decimal number, 2 digits after the decimal point): average time in seconds spent in communication in the time slot concerned for global, CT-N1 and CT-N2, if applicable, agents (integer): number of logged agents available in the time slot concerned, quality of service (qs) 30 (decimal number between 0.00 and 1.00): percentage of calls answered in less than 30 s in the time slot concerned, communication (integer in seconds): sum of agent times in communication in the time slot concerned, production (integer in seconds): sum of agent logged times minus withdrawal times in the time slot concerned, agent load rate (decimal number between 0.00 and 1.00): percentage of time spent online by agent in the time slot concerned.

Note If the “agents” variable was not directly accessible, the centre could provide:

log (integer in seconds): sum of agent log times in the time slot concerned, withdrawal (integer in seconds): sum of agent withdrawal times in the time slot concerned.

The activity data were extracted from the telephony information systems by each participating call centre and sent to EMCC 35 in electronic format (.csv or .xlsx). The data therefore covered two periods of call centre activity, from 05/01/2022 to 31/06/2022 included and from 01/05/2023 to 06/31/2023 included.

No medical or patient data were collected during the entire study. The study protocol was validated by the Rennes University Hospital Ethics Committee on November 14th, 2023. Clinical trial number: not applicable.

Outcomes

The primary outcome of the analysis was the comparison of the QS30 between 2022 and 2023, i.e. before and after implementation of the two-level, but only during the period of the two-level activity deduced from the 2023 data (mainly during the day).

The secondary outcomes were as follows: to carry out this initial comparison taking into account the whole day (24/24 h), to describe the activity of the participating EMCCs, to describe the quality criteria of the centres, to compare their organisations with each other, to explore the links between organisational factors and performance indicators (number of calls, days, weeks and months, average call duration, average agent workload, correlation coefficients between performance indicators and organisational factors).

Data analysis

The centres’ activity and key performance indicators were first presented globally using descriptive statistics

(median, 25th and 75th interquartile range, maximum, and minimum).

The main analysis thus concerned the comparison of the QS30 between the periods of 2022 and 2023 for the concomitant data of the EMCC 35 and 44, the EMCC 86 being used as control, because the two-level had already been set up in 2022. The null hypothesis H0 was that the implementation of two-level did not modify the quality of the activity, and our alternative hypothesis H1 was that two-level allow to improve the quality of the activity and thus to obtain better QS30. Since, as described in the following sub-section, the QS30 did not follow a normal distribution, because it represented a success rate, i.e. the higher it was, the better the quality of EMCC activity, we chose to use a non-parametric Wilcoxon test. This analysis was completed only during the two-level period of activity (mainly during the day) first, then considering the whole day (24/24 h).

Various secondaries analyses were carried out. Firstly, the different organizations implemented in the 3 centres were compared with each other in 2023, again by comparing the QS30. We used a Kruskal-Wallis test to compare a number of groups strictly greater than 2 for data not following a normal distribution. The null hypothesis H0 was that there was no difference between the 3 ways of setting up the EMCC, i.e. that their QS30s were indistinguishable, and our alternative hypothesis H1 was that the three EMCCs for which we had collected the data turned out to have quality results, i.e. different QS30s with one better than the others. If this test proved significant, a test comparing the different QS30 of each centre one by one would then be carried out, using a Dunn test, with adjustment for multiple tests using the Bonferroni method, to conclude whether or not a particular EMCC was superior.

Secondly, we measured: the correlations between the various indicators of interest, estimated using a Spearman correlation coefficient (varying between -1 and 1), to be able to compare the various two-level organisations. In the case of strong collinearity between indicators, correlations were also estimated in a multivariate model using a structural equation model [16]. This type of model makes it possible to estimate several regressions at the same time by associating correlations between covariates.

Thirdly, we attempted to reproduce the model presented in the original article [6], particularly on the data of 2022, i.e. before the implementation of SAS, then to apply it on the data of 2023. The quality of the model and its adequacy to the data was estimated via 3 indicators in the most frequently used for this type of model the “Root Mean Square Error of Approximation” (RMSEA), the “Comparative Fit Index” (CFI) and the “Tucker Lewis Index” (TLI). The model was considered correct if these

indices were respectively less than 0.08 for the RMSEA and greater than 0.95 for the CFI and TLI [17]. The chosen method was implemented in the R code language (version 4.3.2 dated 2023-10-31) using the “lavaan” and “semTools” packages.

If any data were missing or invalid, the investigators contacted the centres that had supplied the data so that they could complete or verify them. Missing or invalid data were excluded from the analysis.

Results

General characteristics

We collected 255,438 calls over the two periods compared and by the three centres combined, which means 152,108 calls during the two-level period; this represents a median of 27 [17–38] calls per hour with a maximum of 133 calls and a minimum of 0 calls. The median duration of calls was 90 [70–108] seconds, with a maximum of 652 s and a minimum of 9 s. The median number of CT-N1 connected per hour was 2.4 [2.0–4.2] over these two periods, and varied between 1 and 10. Their median load rate was 30 [19–39] % with a maximum of 97.2% and a minimum of 0.3%. The median hourly rate of calls answered was 100 [96–100] %, with a minimum of 14.3%. The average QS30 was $89.07 \pm 15.16\%$, with a maximum of 100% success and a minimum of 1.7%. The detailed description of the data by centre is presented in Table 1. The correlation matrix for the different variables studied is presented in Table 2.

Comparative analysis of quality of service by centre

The analysis of the two-level implementation period revealed an evolution for EMCC 35 and 44 (p -value $< 1e-4$). EMCC 35 reduced its QS30 (93.4% vs. 91.2%). EMCC 44 improved its QS30 from 90.7 to 100%. In EMCC 86, the control centre, the QS30 remained at 100% (p -value = 0.1).

In the two-level period, we investigated the differences among the three centres in 2023, focusing on the types of systems implemented. This analysis indicated a significant difference (p -value $< 1e-4$), suggesting the possibility of one system demonstrating superiority over the others. Finally, we conducted iterative tests to determine if any system was superior. No difference was observed between EMCC 44 and EMCC 86 (p -value = 1). A difference was observed between EMCC 35 and EMCC 44 (p -value $< 1e-4$) and between EMCC 35 and EMCC 86 (p -value $< 1e-4$).

A secondary analysis was conducted on all data collected over 24 h, regardless of whether the two-level system was in place. For EMCC 35, the QS30 reached from 91 [79–100] % in 2022 to 93 [83–100] % in 2023 (p -value $< 1e-4$). For EMCC 44, the QS30 reached from 87 [73–97] % to 96 [84–100] % (p -value $< 1e-4$). For

Table 1 Detailed descriptive statistics for the 3 EMCCs over the 2 periods during the two-level period

		2022	2023	Total
EMCC 35	Number of calls	26,854	30,096	56,950
	QS30	93.4 (86.2 ; 98.3)	91.2 (81.1 ; 97.2)	92.6 (83.8 ; 97.9)
	Agent	4.6 (3.7 ; 5.4)	4.6 (3.5 ; 5.63)	4.6 (3.7 ; 5.5)
	Incoming Calls	34 (27 ; 44)	38 (30 ; 51)	36 (28 ; 48)
	Answered Calls	32 (26 ; 43)	37 (29 ; 50)	34 (27 ; 47)
	Rate of ans. calls	97.2 (94.9 ; 100)	97.4 (95.2 ; 100)	97.4 (95.1 ; 100)
	Com. Time	108.7 (98.4 ; 120.4)	106.8 (98.2 ; 117.6)	107.7 (98.2 ; 118.8)
	Load Rate	34.7 (29.7 ; 40.8)	37.5 (32 ; 44.5)	36.1 (30.8 ; 42.9)
EMCC 44	Number of calls	20,011	18,205	38,216
	QS30	90.7 (77.7 ; 98.2)	100 (95.7 ; 100)	96.8 (88.2 ; 100)
	Agent	3 (2.5 ; 3.9)	6.1 (5.3 ; 6.8)	4.6 (2.9 ; 6.1)
	Incoming Calls	44 (37 ; 61)	41.5 (31 ; 60)	43 (34 ; 60.3)
	Answered Calls	42 (34 ; 57)	39 (30 ; 58.3)	41 (32 ; 58)
	Rate of ans. calls	95.2 (91.4 ; 97.9)	97.5 (95.3 ; 100)	96.8 (93.2 ; 98.7)
	Com. Time	118.2 (106.1 ; 130.6)	40.8 (34.7 ; 46.9)	75.8 (40.8 ; 118.1)
	Load Rate	53.7 (44.4 ; 63.2)	34.7 (25.5 ; 44.3)	44.4 (32.8 ; 56.9)
EMCC 86	Number of calls	28,367	28,575	56,942
	QS30	100 (94.4 ; 100)	100 (94.1 ; 100)	100 (94.3 ; 100)
	Agent	2 (2 ; 2)	2 (2 ; 2.4)	2 (2 ; 2)
	Incoming Calls	18 (11 ; 26)	19 (10 ; 26)	19 (11 ; 26)
	Answered Calls	18 (11 ; 26)	19 (10 ; 26)	19 (11 ; 26)
	Rate of ans. calls	100 (100 ; 100)	100 (100 ; 100)	100 (100 ; 100)
	Com. Time	77 (66 ; 90)	83 (69 ; 98)	80 (67 ; 95)
	Load Rate	21.5 (13.4 ; 30.4)	21.8 (13.9 ; 30.2)	21.7 (13.7 ; 30.3)

Number of calls = total number of calls received during the period; Agent = median number of agents logged per hour ; Incoming Calls = median number of incoming calls per hour; Answered Calls = median number of calls answered per hour; Rate of ans. calls = median percentage of calls answered per hour out of total calls received ; Com. Time = median call duration per hour in seconds ; Load Rate = median percentage of time spent online per agent per hour

Table 2 Correlation matrix for both period

	Load rate	A. Calls	QS30	Rate of A. Calls	I. Calls	Com. Time	Agent	Entage
Load Rate	1	0.70	-0.59	-0.22	0.72	0.30	0.27	0.67
A. Calls		1	-0.28	-0.08	0.99	0.03	0.63	0.57
QS30			1	0.41	-0.31	-0.18	0.01	-0.42
Rate of A. Calls				1	-0.13	0.12	-0.09	-0.12
I. Calls					1	0.04	0.63	0.58
Com. Time						1	-0.05	0.07
Agent*							1	-0.15
Entage*								1

Load Rate = median percentage of time spent online per agent per hour; Answered Calls = median number of calls answered per hour; Rate of ans. calls = median percentage of calls answered per hour out of total calls received; Incoming Calls = median number of incoming calls per hour; Com. Time = median call duration per hour in seconds; Agent = number of agents logged per hour; entage = number of calls per agent per hour

EMCC 86, the QS30 reached from 100 [94–100] % to 100 [94–100] % ($p = 0.1$).

Structural equation modulization

The chosen models and associated results are presented in the Fig. 1.

All the indicators show that the 2022 data fit the model (TLI = 0.999, CFI = 1.000, RMSEA = 0.020). However, this is slightly less the case for the 2023 data (TLI = 0.977, CFI = 0.996, RMSEA = 0.055). In the two models, the largest effects between variables in the regression model were observed between: (i) the number of calls received

per agent per hour and the agent workload per hour (0.70 for 2022 and 0.60 for 2023), and (ii) agent workload per hour and QS30 (-0.77 for 2022 and -0.50 for 2023).

Discussion

The EMCC system is undergoing major change with the introduction of the two-level response in France. It is therefore important to monitor its implementation using objective elements to ensure the continuity and quality of the service already in place, and then improve it if necessary. Our study showed that this implementation has led to an evolution of the QS30, but not necessarily towards

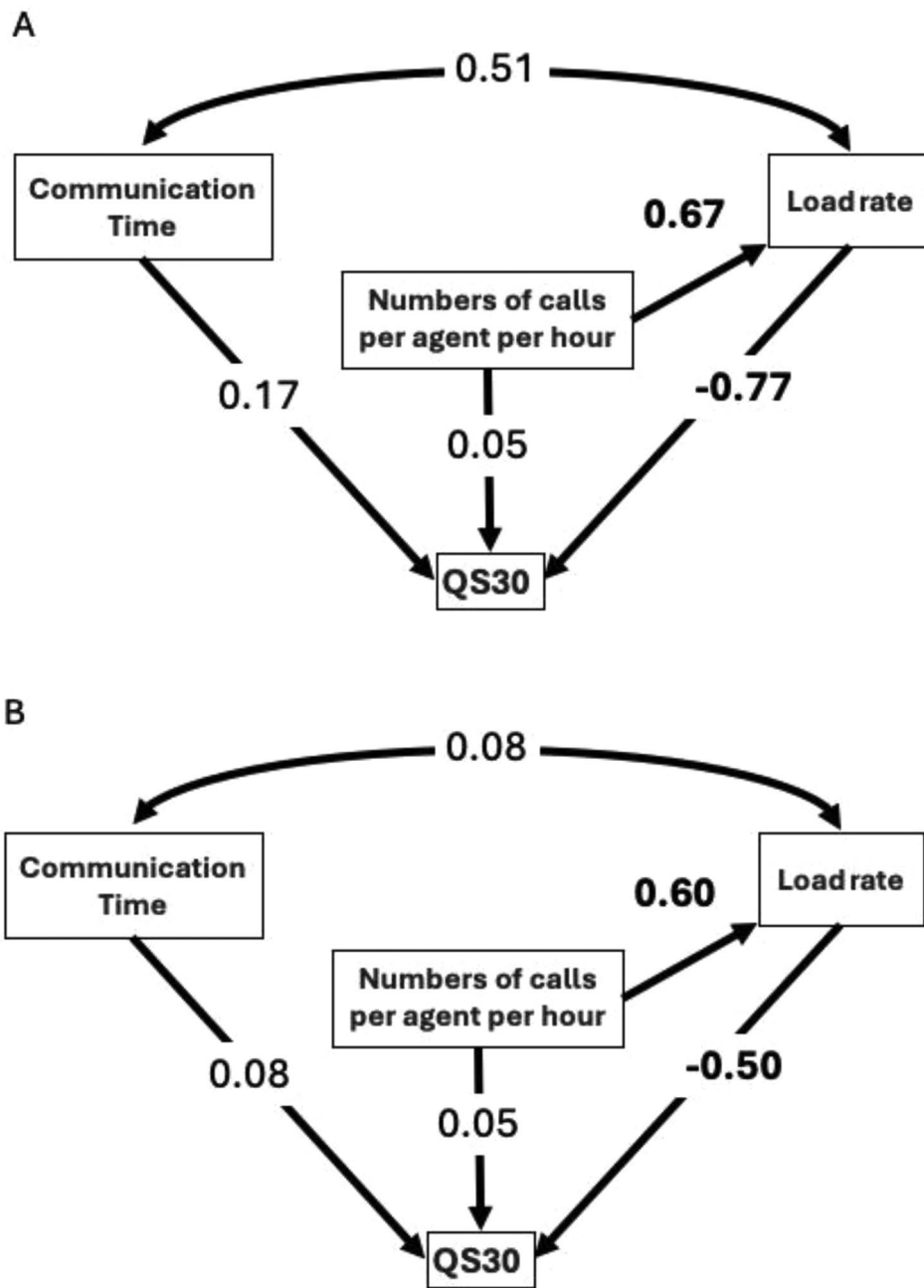


Fig. 1 SEM model and regression coefficient (straight arrows) and covariance coefficient (curved arrow) for the 3 EMCCs during the two-level period on 2022 data (A) and 2023 data (B)

its improvement. The organisation of the response appears to play a determining role in this process.

Several studies have already demonstrated the success of this new system through numerical simulations [11, 12, 13, 14, 15]. This study emphasizes the critical role of two-level systems in enhancing the efficiency of EMCC, in the context of increasing demand for emergency services, based on real data for the first time. The significant improvement in QS30 for EMCC 44 between 2022 and 2023 during two-level period (mainly during the day), supports the hypothesis that the implementation of a two-level positively impacts operational performance. However, the deterioration in the QS30 for the EMCC 35 call this conclusion into question. Disparities in activity trends and response between the two EMCCs may also explain the observed differences: EMCC 44 received fewer calls in 2023 and had more call takers, whereas EMCC 35 experienced an increase in call volume with the same number of call takers. These findings support the conclusions of a simulation study that recommended increasing the number of call takers to ensure an effective two-level response [11]. Nevertheless, when analysing the data on a 24-hour basis, i.e. periods with only one level of call taker, there was an overall improvement in the QS30 for both EMCCs. This suggests that even a partial implementation of the system would improve overall results throughout the day.

We conducted this study across three EMCCs that implemented two-level systems in different ways. The observed stability in performance at the control centre, EMCC 86, underscores the need for innovative organizational strategies to adapt to changing demands. The comparison across the three centres further highlights the potential advantages of different operational models [6]. Notably, the significant differences in QS30 suggest that the structure of the two-level system can influence outcomes. This implies that EMCC 35, with its less comprehensive two-level framework, may require further optimization to reach the performance levels of its counterparts. Indeed, certain intuitive approaches aimed at improving the system, such as increasing the number of call-takers, for example, without a detailed examination of their inter-organization, may have had counterproductive effects [11]. Other features of telephony tools could make it possible to pick up calls more quickly. The two main ones are automatic call distribution (the call is distributed to a call taker rather than to a waiting room) and automatic pick-up (the call taker does not need to click to pick up) [14].

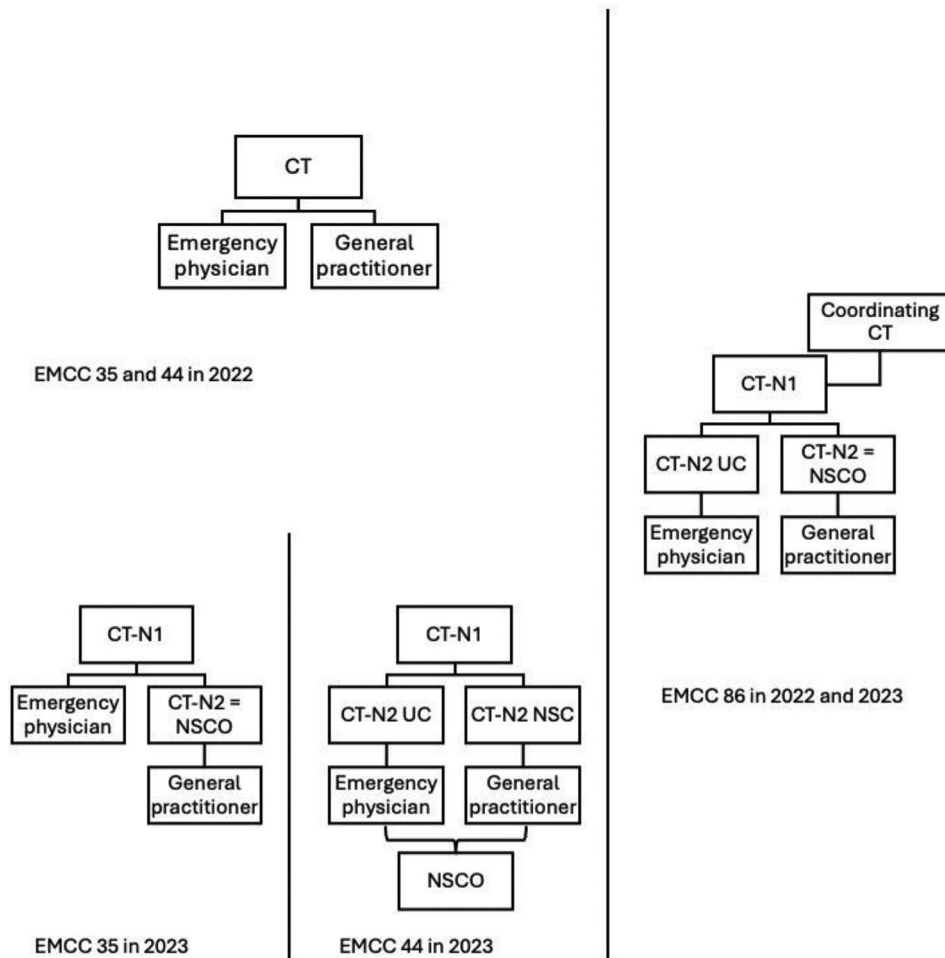
The structural equation modelling indicates strong correlations between key operational variables, such as call volume and agent workload, reinforcing the importance of efficient staffing and resource management. These findings align with those presented in a previous article [6]. Similar conclusions are also reported in studies [11, 13, 14], which use different models built from simulated data and later implemented on real-world data (e.g., fire brigade data). The observed decrease in the strength of these correlations, while still valid, from 2022 to 2023 suggests that as systems evolve, adjustments in operational strategies may be necessary to sustain service quality.

The results should be considered in light of several limitations. First, the activity of EMCCs varies over time. It follows an annual cycle influenced by seasons and holidays [18]. In this study, only two months of the year (May and June) are analysed, which does not allow for the examination of annual variations in the number of calls received and answered. Second, the previous study focused on QS20, whereas we investigated QS30, which has been implemented as the quality control indicator in France since 2019 [6]. This limits direct comparison with the previous study. However, it can be hoped that QS30 will serve as the quality indicator for future national studies, allowing for comparisons between those studies and the one conducted here. Third, SEM models were initially developed under the assumption of multivariate normality (a very common statistical assumption) [16, 17]. However, the nature of the data suggests that it does not follow a normal distribution, and no adaptation of the model has been applied to correct for this. It may therefore be worth exploring other types of regression more suited to the data, such as Poisson or quasi-Poisson models, for this new dataset.

Conclusion

Overall, the findings advocate for a tailored approach to implementing two-level systems across EMCCs, taking into account the unique challenges and characteristics of each centre. Future research should explore the long-term impacts of these organizational changes, as well as potential innovations in technology and training that could further enhance EMCC performance. For instance, it would be valuable to collect data over the course of a full year on a two-level system, to better account for seasonal variations in call volumes, and to perform economic analysis.

Appendix



Appendix Organization of the call pathway according to the EMCC and period. CT: Call taker; NSC: Non-scheduled care; NSCO: Non-scheduled care operators; UC: Urgent Care

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Author contributions

Conception and design: LU, YP, HDF, PGR; acquisition of data: LU, YP, HDF, PGR; analysis: LU; interpretation of data: LU, YP, HDF, PGR; drafting the article: LU and PGR; critical revision for important intellectual content: YP, HDF; final approval of the version to be published: all authors.

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Data availability

The statistical code and technical processes are available from the time of publication. Appropriate institutional agreements will be required for anonymized participant data transfer. Requests should be made via email to the corresponding author along with an analysis proposal.

Declarations

Ethics approval and consent to participate

The study protocol was validated by the Rennes University Hospital Ethics Committee on November 14th, 2023. The trial adhered to the principles of the Declaration of Helsinki.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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