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Original

Enabling policy action using scenario simulation in procedures with guarantees of maximum time to surgery

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A B S T R A C T

Objective: Facilitate policy action using scenario simulation of waiting list situations for each of the surgical procedures in order to establish guarantees of maximum waiting times for surgery.
Method: Using the conceptual framework of queuing theory, management indicators can be defined based on a finite set of parameters, among which are the maximum waiting time guarantee until surgery and the probability of non-fulfillment of the guarantee. These scenarios can be configured on the basis of information from the scientific literature or expert consensus.
Results: The tool developed allows the configuration of waiting list situation scenarios based on a proposed dashboard for monitoring and management.
Conclusions: This scenario-building tool facilitates informed discussions among health authorities and providers to set realistic goals, improve adequacy in surgery indication and decide on capacity adjustments.

Facilitando la toma de decisiones mediante simulación de escenarios en procedimientos con garantías de tiempos máximos de espera

Palabras clave:
Procedimientos quirúrgicos
Listas de espera
Teoría de colas
Sistema sanitario inteligente
Evaluación de procesos
Política sanitaria

R E S U M E N

Objetivo: Facilitar la acción política mediante la simulación de escenarios de situaciones de lista de espera para cada uno de los procedimientos quirúrgicos con el fin de establecer garantías de tiempos máximos de espera para cirugía.
Método: Utilizando el marco conceptual de la teoría de colas, se pueden definir indicadores de gestión basados en un conjunto finito de parámetros, entre los que se encuentran la garantía de tiempo máximo de espera hasta la cirugía y la probabilidad de incumplimiento de la garantía. Estos escenarios pueden configurarse a partir de información procedente de la literatura científica o del consenso de expertos.
Resultados: La herramienta desarrollada permite la configuración de escenarios de situación de lista de espera a partir de un cuadro de mando propuesto para su seguimiento y gestión.
Conclusiones: Construir escenarios de situación de lista de espera con esta herramienta facilita los debates informados entre las autoridades sanitarias y los proveedores para establecer objetivos realistas, mejorar la adecuación en la indicación quirúrgica y decidir ajustes de capacidad.

Introduction

In the context of a National Health System (NHS), waiting lists for elective surgery are routine.[1] The establishment of maximum waiting times has been used to limit the potential negative effects on health due to a late response (e.g., disease progression, increased morbidity, reduced treatment efficacy) while reducing the detrimental impact of uncertainty on patients' quality of life, anxiety, and functional status, and minimising access disparities.[2] Additionally, guaranteeing response times may serve as an explicit incentive for healthcare authorities and providers to focus on improving an effective response to the population's needs and an efficient allocation of resources, enabling benchmarking, while being accountable to a citizenship whose perception of the usefulness of the health system is at stake.[3] Maximum waiting times guarantees were first established in Annex III of RD 605/2003[4] by setting priority levels for inclusion on the waiting list for outpatient consultation and diagnostic/therapeutic tests —with two priority levels and a maximum time guarantee (15 days)— and for surgical indication —with three priority levels for elective procedures and two maximum time guarantees according to each priority level (30 and 90 days respectively)—. Notably, those times were deemed recommended

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rather than mandatory. Subsequently, those guarantees were modified by RD 1039/2011 to a maximum of 180 days for elective surgical procedures and 60 days for outpatient consultation and diagnostic/therapeutic tests.[5] These guarantees are currently reflected in the waiting list information system for the NHS (SISLE) that provides information on the number of patients waiting for an outpatient consultation by speciality and for the most frequent elective surgical procedures, the average waiting time, the population rate of people waiting, and the percentage of people over the guarantees in each case for each region by semester.[6] The purpose of this information is hardly monitoring the status of the waiting list at autonomous communities level and no information on the waiting times for diagnostic and therapeutic testing is available.

We may argue that this type of information system (counts, semestral at autonomous communities level) does not provide evidence meaningful enough to inform policy decision-making. In order to be informative enough and foster policy action, guarantees should be clinically driven and process-specific, stratified by level of clinical severity, and based on the best available evidence or, at least, on a formal consensus from clinical experts.[7] Unfortunately, there is not robust evidence on the time-dependent effectiveness of surgical interventions (which would be the basis to set up time guarantees) and there is a lack of consensus on whether certain conditions would be deemed subject of guarantees, given the uncertainty on which should be the appropriate indication criteria.[3] The lack of certainty about how to set up guarantees has led us to think of an alternative. A potential option has been a scenario-driven simulation approach following the theoretical framework of the queuing theory. In this paper we provide a scenario setting mechanism embedded in an interactive tool that, including procedure-specific information relevant to guaranteeing timely access to surgery, can virtually inform policy making at the autonomous communities level.

Method

Any waiting list can be conceptualized as a queue that can be modeled following queuing theory from the perspective of operational research.[8] In the case of waiting for elective surgery procedures, waiting lists are dependent on a clinical indication for surgery, the acceptance of the intervention by the patient (patient's preferences), the maintenance of the circumstances that lead to the indication of the procedure while waiting, and the capacity of health care services to perform the surgery. Therefore, we can characterise the *demand* for surgery at a certain time as the indication rate subtracting the patients not accepting the intervention and those whose circumstances render them unable to be intervened (i.e., transferred out to another health system, patients recovered, patients who died while waiting, etc.); and the *capacity* of healthcare services as the intervention rate or programmed surgical activity based on the effective use of the specific available resources.

Under equilibrium conditions, when *capacity* is larger or equal to *demand*, the distribution of waiting times in the waiting list for a particular process can be modelled as an exponential decay distribution, complying with Little's Law under which, when capacity exceeds demand, the mean size of the waiting list is equal to the indication rate by the mean waiting time.[9,10] Following this principle, for each procedure, we can estimate the target size of the waiting list by setting a guarantee of maximum waiting time, given a tolerance threshold for cases in which the healthcare services would never comply with the guarantee (i.e., there may be patients above the guaranteed threshold by chance).

We leverage the conceptual framework and equations derived from queuing theory and their particular application to waiting lists, proposed by Fong et al.[11,12] in their preprint *Understanding Waiting Lists Pressures,* to develop a web application in R[13] based on an interactive dashboard in Quarto Live[14] that allows scenarios setting. The dashboard enables the modification of five relevant parameters that depict the situation of the waiting lists in elective surgery procedures currently under guaranteed maximum waiting times (180 days).[4,5] The five parameters that the policy analyst may iteratively modified and simulate are referred to the indication rate (i.e., percentage of people waiting for surgery with an inadequate indication of surgery, and percentage of people leaving the waiting list for causes different than surgery), the guarantee (i.e., maximum time to surgery, and tolerance threshold -expressed as the percentage of people expected to surpass the maximum time), and the rescue time for a health system or health service to control their waiting lists (i.e., expected time to return to the equilibrium of the queue).

The interactive dashboard application provides for each procedure a visualisation of the effect of modifying the maximum waiting time guarantee and the tolerance threshold in the exponential waiting time decay distribution, highlighting the target average waiting time to comply with such guarantee. In addition, the application informs on the average time to surgery, and three actionable indicators: 'distance from the equilibrium', 'relief capacity' and 'target capacity'; so, the 'distance from the equilibrium' is the ratio between the current size of the waiting list and the target size to comply with the expected guarantee; the 'relief capacity' reflects the additional activity per day required to reach the equilibrium within the established rescue time; and, the 'target capacity' represents the additional activity per day required, after controlling the waiting list, to deal with the increased demand. Additionally, a measure of 'waiting pressure' is shown for each surgical procedure considering the ratio between the average waiting time and the target waiting time based on the guarantee. Further detail on the meaning and the calculation methodology for each of these indicators is provided within the tool as contextual information (see Supplementary material).

In order to illustrate the use of this scenario-setting tool, we used as the baseline information, the number of people in the waiting list and the average waiting time for each region extracted from SISLE report from December 2023, published by the Ministry of Health.[15] In addition, we estimated surgery capacity by calculating the ninth percentile (p90), variance, and the numbers of days with surgical activity by region for each procedure using data from the minimum basic dataset at hospital discharge (RAE-CMBD)[16] from January to December 2023.

Results

The interactive web application, namely 'Calculadora escenarios - Listas de Espera Quirúrgica (SNS)' is published as an open source development project, under a creative commons attribution non-comercial 4.0 international licence, at CienciadeDatosySalud/ Variaciones-Cirugías-Electivas/Calculadora_Escenarios.

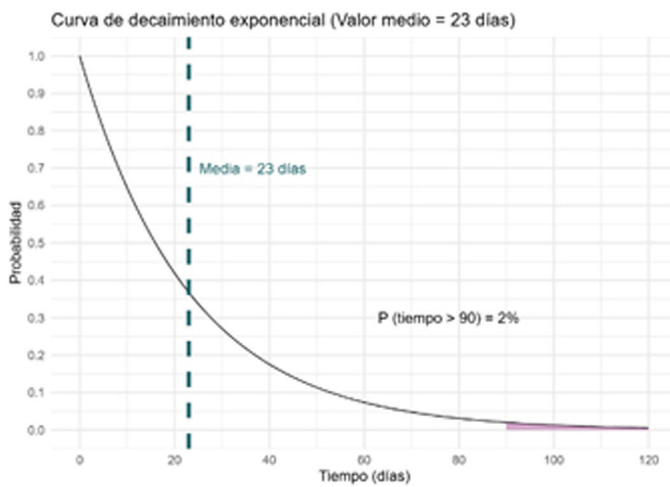
As a matter of illustration of the use of the tool, we have simulated the situation of the waiting list for two different elective procedures, coronary artery bypass graft (CABG) and knee replacement, under a set of input parameters, considering that potential adverse events from delaying a bypass will be, in general, more severe than those from delaying a knee replacement, and that we have some insight on likely percentage of inadequate knee replacement indication in the context of the Spanish National Health System (SNS) (Figs. 1 and 2).[17]

Figure 1 showcases a CABG waiting list scenario considering 5% inappropriate surgical indications, 5% patient attrition, a 90-day maximum wait time (guarantee), a 2% tolerance threshold, and a

Cuadro de Mandos

Proceso:	Bypass coronario	% Indicación inadecuada:	5	% Salidas LEQ no quirúrgicas:	5
% Prob. incumplimiento garantía:	2	Garantía (días):	90	Tiempo hasta equilibrio (días):	180

Escenario Lista de Espera Quirúrgica



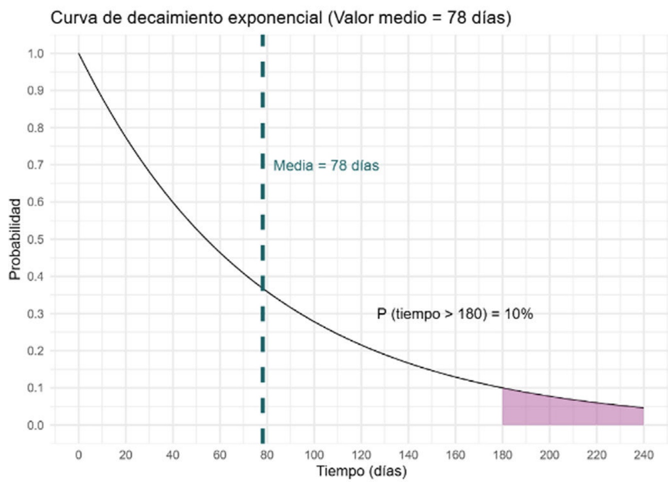
Bypass coronario	Distancia al equilibrio	Capacidad de rescate	Objetivo de capacidad	Demora media	Presión de Espera
Andalucía	1.25	1.03	1.04	57	2.48
Aragón	0.08	0.88	1.04	117	5.09
Asturias					
Baleares	1.88	1.11	1.04	86	3.74
Canarias	0.27	0.91	1.03	56	2.43
Cantabria					
Castilla y León					
Castilla-La Mancha	0.04	5.53		79	3.43
Cataluña					
Comunidad Valenciana	1.1	1.01	1.03	40	1.74
Extremadura					
Galicia					
Madrid	0.35	0.92	1.03	35	1.52
Murcia	0.27	0.91	1.03	31	1.35
Navarra					
País Vasco	0.23	0.9	1.04	36	1.56
La Rioja	0.04	0.88	1.03	16	0.7

Figure 1. Simulation of waiting list situation scenario for coronary artery bypass graft, following the input parameters shown in 'Control panel': 5% of people waiting for surgery with an inadequate indication of surgery, 5% of people leaving the waiting list for causes different than surgery, maximum guarantee time to surgery of 90 days, 2% tolerance threshold and expected time to return to the equilibrium of the queue of 180 days. Each scenario is represented by two panels: a) *left:* exponential decay distribution with a target average waiting time to comply with such guarantee, which is 23 days; the shaded area under the curve corresponds to the percentage of people expected to exceed the maximum guarantee time; and b) *right:* table with 'distance from the equilibrium', 'relief capacity', 'target capacity', 'average waiting time' and waiting pressure per region to comply with such guarantee. Colour legend for 'distance from the equilibrium': green for values below 1 may be interpreted as that they reduce the waiting list in the following period; orange for values between 1 and 2 may be interpreted as that they do not increase the waiting list by taking organisational measures; and purple for values above 2 may be interpreted as that they increase the waiting list irrespective of organisational measures. In these cases extraordinary measures are required (i.e. capacity increase, demand control).

Cuadro de Mandos

Proceso:	Prótesis rodilla	% Indicación inadecuada:	33	% Salidas LEQ no quirúrgicas:	10
% Prob. incumplimiento garantía:	10	Garantía (días):	180	Tiempo hasta equilibrio (días):	180

Escenario Lista de Espera Quirúrgica



Prótesis rodilla	Distancia al equilibrio	Capacidad de rescate	Objetivo de capacidad	Demora media	Presión de Espera
Andalucía	4.3	42.77	17.9	214	2.74
Aragón	3.04	5.57	2.99	170	2.17
Asturias					
Baleares	1.52	1.22	1.02	151	1.93
Canarias	3.53	5.58	2.71	135	1.73
Cantabria	2.78	4.4	2.53	214	2.74
Castilla y León					
Castilla-La Mancha	3.61	4.42	2.1	81	1.04
Cataluña					
Comunidad Valenciana	4.11	7.49	3.21	71	0.91
Extremadura	3.29	10.55	5.38	230	2.94
Galicia					
Madrid	4.26	7.86	3.28	57	0.73
Murcia	3.08	5.49	2.94	119	1.52
Navarra	3.36	2.06	1.03	148	1.89
País Vasco	3.44	4.98	2.43	68	0.87
La Rioja	2.55	1.67	1.02	148	1.89

Figure 2. Simulation of waiting list situation scenario for knee replacement, following the input parameters shown in 'Control panel': 33% of people waiting for surgery with an inadequate indication of surgery, 10% of people leaving the waiting list for causes different than surgery, maximum guarantee time to surgery of 180 days, 10% tolerance threshold and expected time to return to the equilibrium of the queue of 180 days. Each scenario is represented by two panels: a) *left:* exponential decay distribution with a target average waiting time to comply with such guarantee, which is 78 days; the shaded area under the curve corresponds to the percentage of people expected to exceed the maximum guarantee time; and b) *right:* table with 'distance from the equilibrium', 'relief capacity', 'target capacity', 'average waiting time' and waiting pressure per region to comply with such guarantee. Colour legend for 'distance from the equilibrium': green for values below 1 may be interpreted as that they reduce the waiting list in the following period; orange for values between 1 and 2 may be interpreted as that they do not increase the waiting list by taking organisational measures; and purple for values above 2 may be interpreted as that they increase the waiting list irrespective of organisational measures. In these cases extraordinary measures are required (i.e. capacity increase, demand control).

180-day expected return to equilibrium; while Figure 2 presents a knee replacement waiting list scenario, considering a larger 33% inappropriate surgical indications, 10% patient attrition, a 180-day maximum wait time, a 10% tolerance threshold, and a 180-day expected return to equilibrium. Each simulated scenario is presented through two elements: the left-hand side panel illustrating an exponential decay distribution, and the right-hand side panel presenting a table summarizing autonomous communities performance. This table includes the 'average waiting time', 'distance from the equilibrium', the 'waiting pressure', the 'relief capacity', and the 'target capacity' required per region to achieve the specified guarantee. In this table, the 'distance from the equilibrium' is color-coded to indicate its impact on the waiting list dynamics: green for distances lower than 1 (controlled waiting lists); orange for distances between 1 and 2, indicating that organizational measures might suffice to prevent list growth; and purple for distances larger than 2, warning a likely increase in the waiting list, requiring extraordinary interventions to restore the waiting list to compliance with the guarantees within the rescue time (e.g., increasing in-house capacity or purchasing external capacity).

Discussion

Surgical waiting lists for certain elective surgeries keep growing even though the NHS's capacity has increased, and the productivity curve has changed with the incorporation of new surgical approaches and technologies and organisational policies as day-case surgery and early discharge programs. Maximum guaranteed times to surgery, based on clinical priority or severity levels, were introduced in the SNS as health policy in 2011 for certain surgical procedures as a strategy to ensure effective and equal access to healthcare. Although, time-to-surgery guarantees have shown to be scarcely effective in controlling the waiting times, partly because they were set to be not condition-specific nor clearly clinically oriented, and partly because their implementation did not entail enforcement measures and was based on a FIFO-based queuing system. We additionally found that, according to theory, the current waiting list information system of the NHS, although partially allows the monitoring of the waiting lists, does not foster any policy action since it does not jointly consider those key elements in the analysis of the waiting lists (e.g., adequacy of indication, losses in the waiting list, actual capacity, level of acceptance for a condition or tolerance thresholds) and does not provide actionable indicators referred to the efforts to get to the equilibrium in a given (guaranteed) time, as for example, those shown in our approach (i.e., distance to the equilibrium, rescue capacity or effort to keep the waiting list controlled).

Alternatively, the proposed tool yields multiple procedure-specific scenarios to analyse the waiting list situation in each autonomous community with adding some sense to information that exists in the current health information systems (healthcare capacity, waiting list size, and average waiting times) while delivering actionable indicators. Indeed, the scenarios can be easily customized by modifying five input parameters that can be either agreed upon following expert consensus or informed by leveraging medical evidence on clinical effectiveness when available. The tool may be also used to assess the impact of acting upon any single input parameters in controlling the situation of the waiting lists, therefore focusing on high impact measures. For instance, lowering the likelihood of inadequate indication by personalising treatment using prognostic scales or prioritizing indication depending on clinical severity;[18] reducing patient rejection to the intervention by promoting shared decision-making, or setting guarantees adjusted to clinical effectiveness and with adequate compliance level. In addition, the tool presents scenarios focusing on guiding policy decisions in those regions with higher deviations from the equilibrium, those with increasing waiting times and people waiting for surgery, providing information on those regions with better performance that could well serve as exemplary benchmarks; and, making sense out of the difficulties to control the waiting list with the usual organisation measures and the existing resources, eventually backing any decision on recruiting external capacity, analysing the relief capacity and the target capacity indicators.

On a different note, it is essential to acknowledge some caveats for the interpretation of the scenarios associated with the analysis framework and its theoretical constraints, and as a limitation the quality and availability of the information supporting the scenarios simulation. First, the use of this tool as proposed is a novelty in the context of the SNS management of waiting lists, thus not yet tested or validated by health authorities. However, the underlying principles are well-established and similar simulation systems based on queuing theory are used routinely in other national health systems, such as the NHS.[19] Second, the analysis framework assumes that the size of the waiting list at a given time used as a parameter is equivalent to the actual demand; however, this size represents the excess demand, therefore, the estimated relief capacity and target capacity represent an increment over the routine activity. On the other hand, with the information available (a single waiting list including all the priority levels) the exponential decay distribution assumes the homogeneous behaviour of the waiting list, thus not considering that different levels of need would require priority-specific waiting lists. Nevertheless, the tool allows to simulate those priority-specific waiting lists via adjusting the inadequate indication and tightening the guarantee accordingly. In addition, while developing the tool, we constrained all input parameters within reasonable bounds, limiting the flexibility of the scenario generation to those that seemed adequate to the context of the SNS. For instance, the target average waiting time in the tool cannot exceed the maximum guaranteed time, as that suppose that 36.7% of patients on the waiting list would be over the guaranteed time and that would be deemed as an unreasonable scenario.[11,20] Likewise, we restricted the guarantee and the rescue time to a maximum of 365 days and set the combined percentage of inappropriate indications and patient dropouts to remain below 100%. These constraints can be lifted or customised based on particular needs to explore broader scenarios by tweaking the source code. Importantly, the tool is dependent on the quality and availability of information; the better the information the more useful the output would be. Some improvements may come from access to more granular data —at the healthcare area level continuously updated (i.e., weekly or monthly)— and better organisational information regarding the system's operational capacity, and clinical information on patients' severity.

Finally, this tool does not provide a specific response to questions on horizontal (equal clinical need, equal guarantee) or vertical (different clinical need, different guarantee) equity, as this would require leveraging individual-level clinical and socioeconomic data, out of the scope of this decision-aid tool. Nonetheless, the tool offers a scenario-based simulation that builds on two complementary elements; a given guarantee as well as a limitation in the number of patients exceeding the guarantee, which represents the SNS commitment to address equitable access; and, on the adequate indication of effective surgeries that, in the context of a FIFO-based queuing system, raises awareness on the need of concentrating resources in those that are more likely to benefit from the indication of a surgery.

Conclusions

In this paper, we have provided an approach that, supported by an interactive tool, and making sense out of data already produced in the national health system, could virtually facilitate policy making. The scenario-driven approach aims at overcoming the lack of procedure-specific evidence on several demand factors affecting the entry of patients into the queue and the scarcity of granular information on the system capacity to deal with a growing demand. Enabling the construction of multiple scenarios provides a sense on how far from the control of the waiting a health system is, and what would be the effort to comply with the guaranteed times in a given time as well as the effort to keep the list controlled. Finally, this approach may foster an informed conversation between the national and regional health authorities and between health departments and regional providers to pursue credible goals and rationally decide on whether adding capacity is the solution. This approach does not prevent enhancing the health information systems with a view to use more accurate information in the construction of scenarios.

Availability of databases and material for replication

Information on the waiting lists in December 2023 is publicly available at SISLE-SNS Diciembre 2023. Access to data on hospital discharges can be requested based on a research project following the procedure available Secretaría General de Salud Digital, Información e Innovación del SNS. Ministerio de Sanidad. Registro de Atención Especializada (RAE-CMBD). Scripts for replication are available under a Creative Commons 4.0 International Attibution Non-comercial (CC-BY-NC) licence at GitHub: https://github.com/cienciadedatosysalud/variaciones-cirugias-electivas.

Editor in charge

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Transparency declaration

The corresponding author, on behalf of the other authors guarantee the accuracy, transparency and honesty of the data and information contained in the study, that no relevant information has been omitted and that all discrepancies between authors have been adequately resolved and described.

Authorship contributions

F. Estupiñán-Romero and S. Royo-Sierra conceptualised and researched the methodology. S. Royo-Sierra and J. González-Galindo completed the data management, transformation, and analysis. J. González-Galindo, S. Royo-Sierra and F. Estupiñán-Romero developed the web application. All authors participated in writing the original draft. M. Ridao-López, J. Pinilla-Domínguez and E. Bernal-Delgado reviewed and edited the final manuscript, which all authors approved.

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What is known about the topic?

Elective surgery waiting lists are a common aspect of the National Health System (NHS). Maximum waiting times have been established to mitigate potential adverse health consequences of delayed treatment and are reflected in the monitoring information provided by the NHS Waiting List Information System (SISLE). However, the current information system, relying on semestral aggregate counts at the autonomous community level, provides insufficient evidence for informing policy decisions.

What does this study add to the literature?

The tool proposed in this work yields multiple procedure-specific scenarios to analyse the waiting list situation in each autonomous community while adding some sense to information that exists in the current health information systems (healthcare capacity, waiting list size, and average waiting times) while delivering actionable indicators

What are the implications of the results?

Enabling the construction of multiple scenarios provides a sense of how far from the control of the waiting a health system is, what would be the effort to comply with the guaranteed times in a given time, and the effort to keep the list controlled. Finally, this approach may foster an informed conversation between the national and regional health authorities and between health departments and regional providers to pursue credible goals and decide whether adding capacity is the solution. This approach does not prevent the enhancement of health information systems to use more accurate information in the construction of scenarios.

Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gaceta.2025.102521.

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