

Micro-process diagnosis and attribution of delayed first opening of elective surgery: an empirical study based on multi-time point chain

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Abstract

Objective To provide an empirical basis for transforming operating room management from result monitoring to process governance by constructing a multi-time point chain aligned with standard operating procedures, and by identifying specific delay links and bottlenecks of first elective surgery starts. **Methods** A cross-sectional study was conducted using first elective surgeries from August to December 2025 ($N = 1375$). Data were collected at seven time points. Based on the causal chain principle and process dependence principle, a delay attribution model was developed to calculate link-specific delay contributions and conduct attribution analysis. **Results** The post-intervention on-time start rate was 88.9% (1222/1375). Only 14.0% (192/1375) achieved zero delay across the whole chain. In 153 delayed cases after model correction, delay contributions were: preparation before skin incision (T7-T4, 48.6%), delayed ward transfer (T1, 24.0%), late surgeon arrival (T6, 7.6%), anesthesia overtime (T4, 8.1%), late surgical check doctor arrival (T3, 7.5%), and delayed patient room entry (T2, 4.2%). Surgeon-related factors (T6+T3+T7-T4) accounted for 63.7% of total delay. **Conclusion** The surgical team (late primary surgeon, late checker, and slow pre-incision preparation) is the core bottleneck in first-case delay. The attribution model enables precise delay responsibility localization and provides a scientific tool for continuous data-driven operating room process optimization.

Keywords first operation; opening delay; time point chain; process diagnosis; responsibility attribution; operating room management

The operating room is the core platform with the highest resource density and the highest operating cost. Whether the first elective surgery can be started on time not only affects the convergence efficiency of the day's surgery, but also is directly related to patient safety and overall operating efficiency^[1-3]. Our hospital clearly stipulates that the first elective surgery must be started before 9:00 a.m. (9:30 on Wednesday). However, the data of 2024 show that the average on-time opening rate of the whole year is only 52.6%. This phenomenon is not a case. A number of studies at home and abroad have shown that the delay of the first operation is a common problem in the management of the operating room^[4-7]. In order to improve this situation, in August 2025, our hospital launched a series of multidisciplinary process optimization interventions led by nursing teams.

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The traditional effect evaluation mostly stays in the comparison of the overall opening rate changes before and after the intervention. Although this evaluation method that only looks at input and output can judge whether the intervention is effective, it cannot reveal the specific links and bottlenecks of delay [8-9], resulting in the lack of targets for continuous improvement [10]. In recent years, methods such as process management, six sigma, and multidisciplinary collaboration have been widely used to improve the efficiency of operating rooms [3,7,11-13]. However, most studies still focus on the improvement of macro indicators, [14-16] lack of refined diagnostic tools for micro processes.

Based on this, this study introduced a multi-time point chain analysis framework and constructed an attribution model for the delay in the opening of the first elective surgery. The aim is to use high-precision time chain tools to perform anatomical process diagnosis in the post-intervention stage ; through the responsibility attribution model, the delay contributions of anesthesia, surgery, operating room nursing, ward nursing and other parties are separated one by one ; through the improvement of macro indicators, we can find out the micro imbalance links that have not yet been solved, and provide real targeted decision-making basis for follow-up management. [17-19]

1 Data and Methods

1.1 General information

All the first elective surgeries in the central operating room of our hospital from August 1,2025 to December 31,2025 were selected. After excluding cases of emergency, temporary cancellation and missing data at key time points, 1375 valid data were finally included.

1.2 Methods

1.2.1 Definition of standard time point chain

In this study, under the coordination of the management department, seven key time nodes and their standards for the first elective surgery were set through surgical communication. Considering Wednesday 's special arrangement, the standard is divided into two categories :

Table 1. Standard time point chain for first elective surgery

Time point	definition	Non Wednesday standard	Wednesday standard
T1	ward sent patients to the waiting room	$\leq 07:40$	$\leq 08:10$
T2	nurses received patients into the operating room	$\leq 08:00$	$\leq 08:30$
T3	surgical check doctor in place	$\leq 08:00$	$\leq 08:30$
T4	anesthesia operation completed	$\leq 08:40$	$\leq 09:10$
T5	instrument preparation completed	$\leq 08:50$	$\leq 09:20$
T6	surgeon in place	$\leq 08:50$	$\leq 09:20$
T7	operation opening / skin incision	$\leq 09:00$	$\leq 09:30$

1.2.2 Delayed contribution attribution model

1.2.2.1 Surgical procedures are interlinked, and two basic principles should be followed when judging delayed liability :

Causal chain principle : if the previous link is delayed, resulting in a passive delay in the subsequent link, even if the subsequent link exceeds its own standard, its delay responsibility is still attributed to the initial delay link.

The principle of process dependence : some of the follow-up links must be completed before the specific pre-order link can be started (such as equipment preparation T5 must be subject to tripartite verification, that is, T3 can be completed). If the subsequent start is delayed due to the unfinished pre-order, this part of the delay is also attributed to the pre-order link.

1.2.2.2 Based on the above principles, combined with the standard duration of anesthesia operation 40 minutes (T4-T3), the standard duration of instrument preparation completion 50 minutes (T5-T3), and the standard duration from anesthesia to opening 20 minutes (T7-T4), the following attribution model was established :

Table 2. Delayed contribution attribution model

Delay link	Calculation formula	Responsibility attribution	Remarks
T1 delay	$\text{MAX}(0, T1 - \text{standard time})$	Ward nurse	T1 is the starting point of all subsequent links, and its delay will be transmitted downstream.
T2 delay	$\text{MAX}(0, T2 - \text{MAX}(T1, T1\text{standard time}) - 20)$	Operating room nurses	If T1 has been delayed, the responsibility of T2 is only to examine whether it is based on T1 additional delay time ; if T1 is not delayed, it is examined whether T2 exceeds its own standards.
T3 delay	$\text{MAX}(0, T3 - \text{standard time})$	Surgical verification of doctors '	T3 delay not only affects themselves, but also leads to passive delay of T4 and T5.
T4 delay	$\text{MAX}(0, (T4 - T3) - 40)$	Anesthesiologists	start timing from T3 in place to exclude the interference of the previous delay.
T5 delay	$\text{MAX}(0, (T5 - T3) - 50)$	Operating room nurses	started timing from T3 in place to exclude the interference of pre-order delay.
T6 delay	$\text{MAX}(0, T6 - \text{standard time})$	The main knife doctors '	main knife in place time is relatively independent, less affected by the previous order, and directly examines whether it exceeds the standard.
T7-T4 delay	$\text{MAX}(0, (T7 - T4) - 20)$	The surgical team	refers to the time between the completion of anesthesia and the skin incision, which mainly involves the operation efficiency of the surgeon.

1.2.3 Collection and calculation

For each delayed operation (T7 later than standard time), the number of delayed minutes in the above seven links was calculated respectively. The proportion of the delay minutes of each link to the total delay minutes (T7 actual time-standard time) is the contribution of this link to the delay of this case.

1.3 Statistical analysis

SPSS 26.0 software was used. The count data were expressed as the number of cases and percentage, and the χ^2 test was used for comparison between groups. $P < 0.05$ was considered statistically significant.

2 Results

2.1 Overall opening rate

From August to December 2025, a total of 1375 patients were included in the first elective surgery, of which 1222 were on time ($T7 \leq$ standard time), with an overall on-time opening rate of 88.9 %.

2.2 Micro-process diagnosis after intervention

2.2.1 Overall compliance of the time chain

Of the 1375 surgeries, only 192 (14.0 %) achieved zero delay from T1 to T7. Up to 86 % of surgeries have at least one timeout.

2.2.2 Compliance rate of each link

The compliance rate at each key time point after intervention (actual time $\leq$ standard time of the day) is as follows :

Table 3. Compliance rate of each key time-point link

The number of cases	reaching the standard	rate of links
T1 (send patients to waiting room)	1018	74.0%
T2 (nurse access to operating room)	1165	84.7%
T3 (check the doctor in place)	317	23.1%
T4 (completion of anesthesia)	1273	92.6%
T5 (instrument preparation completed)	1359	98.8%
T6 (surgeon in place)	1148	83.5%

2.2.3 Length of anesthesia operation

The average duration of anesthesia (T4-T3) was 25.8 ± 10.9 minutes, with a median of 25 minutes. 92.6 % (1273 / 1375) of anesthesia operations were completed within 40 minutes of standard time.

2.2.4 Comparison of delayed contribution after attribution model correction

The 153 cases of delayed surgery were decomposed, and the contribution of each link and the average delay time were as follows :

Table 4. Delay contribution and average delay time by link

delay link	Contribution	Average delay time (minutes)
T7-T4 delay (preparation before skin incision)	48.6%	14.7
T1 delay (delay in sending patients)	24.0%	44
T4 delay (anesthesia timeout)	8.1%	11.9

delay link	Contribution	Average delay time (minutes)
T6 delay (surgeon late)	7.6%	11.1
T3 delay (surgical check doctor late)	7.5%	6.9
T2 delay (patient admission late)	4.2%	15.2
T5 delay (instrument preparation delay)	0.0%	0

The 153 cases of delayed surgery were decomposed, and the contribution of each link and the average delay time were as follows :

The total contribution of each team : surgical team (T6 + T3 + T7-T4) : 63.7 % ; anesthesia team (T4 anesthesia timeout) : 8.1 % ; operating room nursing team (T2 + T5) : 4.2 % ; the ward nursing team (T1) : 24.0 %.

3 Discussion and suggestion

3.1 Methodological breakthrough: from fuzzy attribution to responsibility penetration

This study constructs a responsibility-penetrating attribution model based on multi-time point chain. The model clarifies the responsibility of each key time node, and can realize the accurate backtracking and cause positioning of each case of inaccurate open surgery.

In clinical practice, the delay in the opening of the first operation is often generally attributed to a single factor such as slow anesthesia operation, delayed connection or insufficient preparation, resulting in a lack of objective basis for management accountability and difficulty in focusing on improvement measures. The attribution model established in this study can effectively distinguish between active delay and passive delay by introducing the principle of causal chain and the principle of process dependence, so as to avoid the chain effect caused by the delay of the previous link being wrongly attributed to the subsequent link. For example, when the check doctor is late to delay the start of anesthesia, the model restores the delay responsibility to the check link, rather than simply determining that the anesthesia operation is overtime.

In addition, the model has the following clinical practical value : First, the precise stripping of delay responsibility can be realized, and the contribution of each team (including surgery, anesthesia, nursing and ward) to the total delay can be quantified on a case-by-case basis ; the second is to identify the hidden bottlenecks in the process, such as the neglected problem of checking that the doctor ' s arrival rate is less than 30 % for a long time ; the third is to provide operational targets for continuous improvement, so that managers can formulate interventions for specific links, rather than generally strengthen overall management. Through the above mechanism, this model promotes the transformation of operating room management from result-oriented extensive assessment to process-oriented fine governance.

3.2 Bottleneck precise positioning: surgeons are the absolute core

After the attribution model correction, the surgeon-related factors contributed a total of 63.7 % of the opening delay, including the late arrival of the surgeon (T6), the late arrival of the surgical check doctor (T3), and the delayed preparation before skin incision (T7-T4). The results are consistent with the conclusions of many international studies. [5,7,10,12,20]

Among them, the delay in preparation before skin incision (T7-T4) contributed 48.6 %, which was the primary bottleneck of the delay in the first operation. This link corresponds to the operation stage from the patient ' s admission to the skin incision, including steps such as disinfection, towel laying, position placement, and preoperative positioning, suggesting that there is a large room for improvement in the preoperative preparation efficiency of the surgical team in the operating room. [10, 20-21]

The contribution of surgical verification to the doctor's delay in arrival (T3) was 7.5 %, which was a stubborn bottleneck. Checking the doctor's arrival rate is less than 30 %, which is an obvious weak link. This link is located at the front end of the process, and its delay not only directly delays the anesthesia start time (T4), but also leads to passive delays in subsequent links such as instrument preparation (T5), resulting in a chain of efficiency losses. [22]

The contribution of the main surgeon's delay in place (T6) was 7.6 %, which was a hidden bottleneck that had been neglected for a long time. This delay is mostly related to institutional conflicts such as morning rounds and outpatient arrangements, and because its occurrence node is close to the opening time, the buffer space is limited, which has a significant impact on the overall punctuality rate. [12]

3.3 Analysis of patient delay

The attribution model showed that 24.0 % of the patients were sent to the waiting room (T1 delay), with an average delay time of 44 minutes, ranking second among all delay links. This link is located at the forefront of the process, and its delay will be transmitted to the downstream step by step, resulting in passive delay of T2 (patient admission), T4 (anesthesia operation), T7 (platform opening) and other links. Different from the back-end link, T1 delay lacks any compensation buffer, and its impact on the overall opening time is irreversible. In traditional management, T1 delay is often classified as the overall problem of the ward delivery process, lacking special tracking and responsibility assessment. The document data showed that the T1 compliance rate was only 74.0 %, which was at a low level in all links. However, previous discussions focused on the surgery and anesthesia team, and the systematic improvement of the ward link has not received enough attention.

3.4 The real contribution of the anesthesia and nursing team: the masked efficiency compensator

After correction by the attribution model, the true contribution of anesthesia operation timeout (T4 delay) to the total delay was 8.1 %. In all 1375 operations, 92.6 % of the anesthesia operations were completed within 40 minutes of the standard time, and the average operation time was 25.8 minutes, which was significantly lower than the standard upper limit. More importantly, the model eliminates the passive delay of anesthesia initiation caused by the delay of the surgical check doctor (T3 delay) through the causal chain principle, and restores the real time consumption of the anesthesia operation. The above data show that the anesthesia team is not the main source of delay in the current process, and its operation efficiency has high stability and reliability. [23]

The performance of the operating room nursing team is also worthy of objective affirmation. The nursing team involved two key links : patient admission (T2) and instrument preparation (T5). The attribution model showed that the contribution of T2 delay was 4.2 %, and the contribution of T5 delay was 0.0 %. Among them, the compliance rate of T5 link is as high as 98.8 % (1359 / 1375), which is the best in all time nodes.

On the whole, the anesthesia team and the operating room nursing team played the role of efficiency compensator in the first operation process. Under the external interference such as the late arrival of the check doctor and the failure of the surgeon, the two teams partially compensated for the efficiency loss of the front end of the process by compressing their own operational flexibility and maintaining a high compliance rate.

3.5 Vulnerability of macro performance: hidden crisis under high punctuality rate

After the intervention, the overall punctuality rate was 88.9 %, but the zero delay rate of the whole process was only 14.0 %, and up to 86.0 % of the surgeries had at least one link timeout. This contrast shows

that the current high punctuality rate is not due to the coordinated operation of the whole process, but depends on the anesthesia and nursing team to passively compensate the front-end delay by compressing its own operational flexibility. This model focuses process pressure on a few efficient teams and has significant vulnerability. Once encountering complex cases or manpower shortage, the overall performance is difficult to maintain. Therefore, process health should be reflected in the balanced improvement of the compliance rate of each link and the substantial growth of the zero delay rate of the whole process, rather than relying on the high-intensity emergency substitution of individual teams. Follow-up management should focus on the precise management of front-end bottlenecks, reduce excessive dependence on back-end compensation mechanisms, emphasize the joint responsibility of surgeons, anesthesiologists, and nursing teams, and build a more resilient surgical process system. ^[15]

3.6 Precision governance strategy

3.5.1 For the surgical team : Establish a personal performance file, and regularly push the department director and the scalpel to the department director and the scalpel. The department average and individual abnormal values of the surgeon ' s on-time rate (T6), the surgical checker ' s on-time rate (T3), and the length of preparation before skin incision (T7-T4). ^[7] For those who are late for high frequency or overtime for preoperative preparation, rigid constraint mechanisms such as the reduction of qualification for the first operation can be explored. ^[24]

3.5.2 For the ward nursing team : establish a ward-operating room linkage scheduling mechanism, build an information-based two-way feedback system, and optimize the preoperative preparation process standards. To streamline and list the preparatory operations before the patient ' s transfer, formulate standard operating procedures, and clarify the person in charge of each operation and the time limit for completion. For complex cases, the preparation process can be started in advance and sufficient operation time can be reserved. ^[23,25]

3.5.3 For the anesthesia team : T3-T4 linkage assessment was implemented to restore responsibility to the real source of delay. A special review was conducted for a small number of cases (8.1 % contribution) with anesthesia operation timeout, focusing on improving the anesthesia plan ability and operation efficiency of complex cases.

3.5.4 For the operating room nursing team : consolidate the advantages. Continue to maintain the efficient operation of equipment preparation (T5), and promote the standard operation process of this link as a training template to other operating room management scenarios. Optimize weak links. For the T2 (patient admission) link, the focus is on improving the handover process with the ward to reduce the passive waiting caused by incomplete patient information, inadequate transport tools or poor communication. It is possible to explore the establishment of a special post for operating room scheduling, to coordinate the timing of patients entering the room, and to avoid the congestion and waiting caused by the centralized entry of multiple operations.

3.5.5 For preoperative preparation (operation before skin incision) : the operation of intraoperative positioning, special position placement, disinfection towels and other operations are streamlined and standardized, and standard operating time is formulated and incorporated into the routine training and simulation exercise system ^[14]. For repeated overtime operators or procedures, special skills training or video review analysis can be carried out to improve operational proficiency and team cooperation efficiency.

3.7 Research limitations

This study is a single-center cross-sectional study, and the conclusion extrapolation should be cautious. At the same time, there is a lack of detailed time point data of the control group in the same period of 2024, and it is impossible to make a refined comparison before and after the intervention.

The above limitations also laid the foundation for subsequent research. The attribution model established in this study is transferable, and its universality can be verified by multi-center application. The current data can be used as a baseline reference for continuous improvement. The research team has initiated normalized data collection and promoted the transition from cross-sectional diagnosis to dynamic process assessment. The research limitations can be transformed into the starting point of the long-term monitoring system, rather than the end point of the validity of the conclusion.

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References

- [1] Firdi M, Ayine B, Mekete G, et al. Root causes of first-case start time delays for elective surgical procedures: a prospective multicenter observational cohort study in Ethiopia. *BMC Surg.* 2024;24:215.
- [2] Overdyk FJ, Harvey SC, Fishman RL, et al. Successful strategies for improving operating room efficiency at academic institutions. *Anesth Analg.* 1998;86(4):896-906.
- [3] Zhang Mingxia, Zhou Ningning, He Minzhi, et al. Analysis of the impact of process management on the operating efficiency of the operating room [J].*Hospital Management Forum*, 2020 (6) : 35-37.
- [4] Tsai MH, Hudson ME, Emerick TD, et al. The true relevance of first-case start delays. *Am J Surg.* 2015;209(3):427-429.
- [5] Joos C, Bertheau S, Hauptvogel T, et al. Delayed incision time of the first case: analysis of incidences and causes and the effect of list planning instability. *Chirurg.* 2021;92(2):137-147.
- [6] Kimbrough CW, McMasters KM, Canary J, et al. Improved operating room efficiency via constraint management: experience of a tertiary-care academic medical center. *J Am Coll Surg.* 2015;221(1):154-162.
- [7] Morel SD, Gomez NAG. Improving on-time first case starts: an integrative review and quality improvement project plan. *J Perianesth Nurs.* 2021;36(6):717-723.
- [8] Charlesworth M, Pandit JJ. Rational performance metrics for operating theatres, principles of efficiency, and how to achieve it. *Br J Surg.* 2020 Jan;107(2):e63-e69. doi: 10.1002/bjs.11396. PMID: 31903597.
- [9] Fixler T, Wright JG. Identification and use of operating room efficiency indicators: the problem of definition. *Can J Surg.* 2013;56(4):224-226. doi:10.1503/cjs.020712
- [10] Guzmán-Ruiz S, Gómez-Durán EL, Vila-Caral P, et al. The trickle-down effect of first-case tardiness on last-case cancellation rates and operating room overutilization. *Perm J.* 2023;27:22.283.
- [11] Mathews L, Kla KM, Marolen KN, et al. Measuring and improving first case on-time starts and analysis of factors predicting delay in neurosurgical operating rooms. *J Neurosurg Anesthesiol.* 2015;27(3):203-208.
- [12] Wright JG, Roche A, Khoury AE. Improving on-time surgical starts in an operating room. *Can J Surg.* 2010;53(3):167-170.
- [13] Application of Six Sigma management tools combined with information system in improving the efficiency of operating room [J].*China Medical Science*, 2020,10 (19) : 187-190.
- [14] Xuan Wei. Application of operating room process optimization based on multidisciplinary teamwork in laparoscopic cholecystectomy [J].*Modern Journal of Integrated Traditional Chinese and Western Medicine*, 2020, 29 (10) : 1116-1119.
- [15] Han SJ, Rolston JD, Zygorakis CC, et al. Preventing delays in first-case starts on the neurosurgery service: a resident-led initiative at an academic institution. *J Surg Educ.* 2016;73(2):291-295.
- [16] Saw N, Vacanti JC, Liu X, et al. Process redesign to improve first case surgical starts in an academic institution. *J Invest Surg.* 2015;28(2):95-102.

- [17] Pashankar DS, Zhao AM, Bathrick R, et al. A quality improvement project to improve first case on-time starts in the pediatric operating room. *Pediatr Qual Saf.* 2020;5(4):e305.
- [18] Veen-Berkx E, Elkhuisen SG, Kalkman CJ, et al. Successful interventions to reduce first-case tardiness in Dutch university medical centers: results of a nationwide operating room benchmark study. *Am J Surg.* 2014;207(6):949-959.
- [19] Wu A, Kodali BS, Flanagan HL Jr, et al. Introduction of a new electronic medical record system has mixed effects on first surgical case efficiency metrics. *J Clin Monit Comput.* 2017;31(5):1073-1079.
- [20] Saul B, Ketelaar E, Yaish A, et al. Assessing root causes of first case on-time start (FCOTS) delay in the orthopedic department at a busy level II community teaching hospital. *Cureus.* 2022;14(9):e36719.
- [21] Bauer CMC, Greer DM, Wist KBV, et al. First-case operating room delays: patterns across urban hospitals of a single health care system. *J Patient Cent Res Rev.* 2016;3:125-135.
- [22] Phieffer L, Hefner JL, Rahmanian A, et al. Improving operating room efficiency: first case on-time start project. *J Healthc Qual.* 2017;39(2):70-78.
- [23] Halim UA, Khan MA, Ali AM. Strategies to improve start time in the operating theatre: a systematic review. *J Med Syst.* 2018;42(9):160.
- [24] Nguelewou EL, Lawson RM. A Quality Improvement Initiative to Improve First-Case On-Time Starts for Elective Surgeries. *J Dr Nurs Pract.* 2025 Jan 27;JDNP-2024-0008.R1. doi: 10.1891/JDNP-2024-0008. Epub ahead of print. PMID: 39870424.
- [25] Fowler HL. An examination of the literature surrounding leadership and change management to implement a Golden Theatre Initiative: reducing inefficiencies within a neurosurgical operating department. *J Perioper Pract.* 2025;35(6):234-243.