Root Cause Analysis and Actions for the Prevention of Medical Errors: Quality Improvement and Resident Education

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abstract

The quality of care delivered by orthopedic surgeons continues to grow in importance. Multiple orthopedic programs, organizations, and committees have been created to measure the quality of surgical care and reduce the incidence of medical adverse events. Structured root cause analysis and actions (RCA²) has become an area of interest. If performed thoroughly, RCA² has been shown to reduce surgical errors across many subspecialties. The Accreditation Council for Graduate Medical Education has a new mandate for programs to involve residents in quality improvement processes. Resident engagement in the RCA² process has the dual benefit of educating trainees in patient safety and producing meaningful changes to patient care that may not occur with traditional quality improvement initiatives. The RCA² process described in this article can provide a model for the development of quality improvement programs. In this article, the authors discuss the history and methods of the RCA² process, provide a stepwise approach, and give a case example. [Orthopedics. 2017; 40(4):e628-e635.]

Providing both quality care and patient safety has become the foundation of medical decision-making and health care policy implementation. As new organizations are developed and policies are enacted, orthopedic physicians are expected to understand quality and safety mandates and to adapt their practice to comply with these mandates. However, this complicated culture of quality and safety can be difficult to navigate, and when resources are limited, it can be difficult to determine how best to acclimate a practice to this environment. At the same time, orthopedists are expected not only to become familiar with these concepts but also to educate residents on them. Current concepts include hospital-acquired conditions, never events, value-based purchasing, quality indicators, and reporting of adverse events.

Alphabet Soup of Quality Initiatives

The Centers for Medicare & Medicaid Services (CMS) recently selected a group of complications and labeled them hospital-acquired conditions. Under the Deficit Reduction Act of 2005, hospital-acquired conditions were identified as “reasonably preventable through application of evidence-based guidelines.” These complications were recognized as high-risk, and the Accreditation Council for Graduate Medical Education has a new mandate for programs to involve residents in quality improvement processes. Resident engagement in the RCA² process has the dual benefit of educating trainees in patient safety and producing meaningful changes to patient care that may not occur with traditional quality improvement initiatives. The RCA² process described in this article can provide a model for the development of quality improvement programs. In this article, the authors discuss the history and methods of the RCA² process, provide a stepwise approach, and give a case example. [Orthopedics. 2017; 40(4):e628-e635.]

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cost and high-volume issues that contributed significantly to patient morbidity. In 2008, to curtail Medicare and Medicaid expenditures, payments for hospital-acquired conditions were revised, offering incentive for providers to develop quality initiatives to reduce hospital-acquired conditions and subsequently limit their economic burden.2

In 2003, the National Quality Forum described “never events” as occurrences that cause patient harm and are completely preventable when reasonable precautions are taken.3 The National Quality Forum prompted the Joint Commission and the American Board of Orthopaedic Surgery to publish comprehensive guidelines and universal protocols to prevent never surgical events.4 Most notably, presurgical checklists were developed to avoid wrong patient, wrong procedure, and wrong site surgeries. In 2015, correct use of these measures became part of payment determination.5

Hospital Value-Based Purchasing is a CMS initiative that rewards acute care hospitals with incentivized payments for the quality of care that they provide to Medicare beneficiaries.6 The Affordable Care Act of 2010 established the Value-Based Purchasing program and stated that hospitals would no longer be paid solely based on the quantity of services they provide.7 As a result, rewards reflect how closely hospitals follow best clinical practices and how well they enhance patients’ experiences of care during hospital stays. Currently, the CMS rates hospital performance on approved quality domains, including clinical process of care, patient experience of care, outcomes, and efficiency. To determine reimbursement, the CMS scores hospitals on these domains and compares the scores with national averages.8

The Agency for Healthcare Research and Quality9 developed an array of quality indicators to measure health care delivery. Quality indicators are tracked by the CMS, and penalties are implemented for violating best practices. For example, fines for excessive readmission within 30 days of discharge have been increasing steadily since 2012 and are now being expanded to postacute settings.10 Hospitals can use quality indicators to identify potential problem areas.

Tracking Adverse Events

Reporting of adverse events encompasses mistakes, close calls, near misses, active errors, and latent errors that directly cause or can potentially cause patient harm. Modalities for identifying and reviewing adverse events consist of morbidity and mortality conferences, malpractice claims analysis, administrative data analysis, chart review, and observation of clinical care.11 Arguably, the most important modality for assessing adverse events is reporting systems. Adverse events that are witnessed or committed by health care providers are reported via various reporting systems, and their use is strongly endorsed by the Institute of Medicine.12 Analysis of reports may provide rich information about adverse events, and these reports provide a means to involve providers in quality improvement projects.

In conjunction with the Accreditation Council for Graduate Medical Education, quality improvement has become a new focus of the core competencies of orthopedic resident education.13 Residents are now expected to identify causes of system errors and initiate measures to change potentially harmful practice habits.14 Common strategies to promote resident education in understanding patient safety concepts include didactic lectures and morbidity and mortality conferences. However, a recent survey of orthopedic residents and educators found inconsistent methods of instruction and cited “clinical observation” as the most common method of teaching.15 For quality and safety education to be successful, the authors believe that these modalities should be supplemented with applied experiential learning, and a formal process to help residents to improve health care delivery is necessary. This article describes a resident-based model that uses root cause analysis and actions (RCA2) as an effective and efficient means to promote patient safety as a complement to the patient safety structure in place in a specific department or health care system.

Root Cause Analysis and Actions

In 1966, Donabedian16 introduced the concepts of structure, process, and outcomes to examine the delivery of quality health care. When applied to orthopedics, the Donabedian model suggests that care structures (eg, a dedicated arthroplasty team) and processes (eg, standardized arthroplasty protocols) can affect patient outcomes.17 The concepts of structure and process are used as part of the RCA2 process.

The RCA2 process is a systematic, retrospective approach with the goal of discovering the causes of close calls and adverse events to identify measures for prevention.18 The goal is to understand what happened, why it happened, and most importantly, what can be done to prevent it from happening again. It is the task of RCA2 analysts to look beyond human error to identify system issues that contributed to or resulted in the close call or adverse event.

General principles of RCA2 are to identify system factors that resulted in a harmful or potentially harmful outcome to determine what behaviors, actions, inactions, procedures, or conditions must be altered to prevent recurrence. To be effective, RCA2 must be performed systematically and supported by documented evidence. A thorough analysis may find more than 1 root cause. Corrective actions should address all root causes to prevent recurrence. To be successful, RCA2 should not be punitive, and effective outcomes may require other forms of departmental support.

In the health care setting, RCA2 is implemented after an adverse event has been
reported. Data gathering ensues, with detailed review of documents and charts as well as investigative interviews with individuals involved in the event. Tools to assist the team in gathering data include triggering questions, the 5 rules of causation, and an action hierarchy.\textsuperscript{19} Flow diagrams help to establish an event time line, and an event story map adds significant detail. A cause and effect diagram helps to answer why the event occurred and assists in identifying root causes and contributing factors. After root causes and contributing factors are generated, corrective actions are developed to prevent the adverse event from recurring or to prevent patient harm. Solutions are most effective when they are within the institution’s control and do not introduce unintended consequences. Measuring the effectiveness of an intervention is also planned to determine the success of the RCA\textsuperscript{2}.

Previous RCA\textsuperscript{2} processes that included measuring the effectiveness of actions have successfully reduced wrong patient, wrong site, and wrong side surgical procedures.\textsuperscript{20,21} Despite promising implementation, the effectiveness of root cause analysis has been criticized for insufficiently mitigating risk because the same errors can still occur. One reason for this is that the quality of RCA\textsuperscript{2} processes can vary across facilities. Further, errors may be repeated because many RCA\textsuperscript{2} processes are conducted incorrectly or incompletely.\textsuperscript{22} If the true root cause of an event is misunderstood, inappropriate barriers to prevent recurrence may be implemented.\textsuperscript{23} In a study of health care professionals conducting root cause analysis, most respondents reported that their preventive strategies were implemented incompletely.\textsuperscript{24} These shortcomings highlight the complexity of the process and were the driving force for the development of the RCA\textsuperscript{2} process.\textsuperscript{19} When combined with departmental leadership, RCA\textsuperscript{2} can be used to improve patient safety and reduce adverse events.

**HOW TO CONDUCT ROOT CAUSE ANALYSIS AND ACTIONS**

The goal of the RCA\textsuperscript{2} process is to protect patients by identifying and changing factors within a health care system that can potentially lead to harm. However, before the RCA\textsuperscript{2} process can begin, honest and open reporting of errors is required and should be supported and facilitated by departmental leadership.\textsuperscript{25} For example, the Department of Orthopaedic Surgery at the study institution strongly encourages residents, mid-level providers, and faculty to report adverse events and close calls to the department’s patient care committee for monthly confidential peer review. The committee completes its review and identifies adverse events or close calls that are believed to be suitable for RCA\textsuperscript{2}. Ideal cases are recent occurrences because of the increased likelihood that involved staff will recall the details of the event and will be available for interviews.

Once an adverse event or close call is deemed suitable for the RCA\textsuperscript{2} process, a team of individuals with fundamental knowledge of the event is selected. In these department-level reviews, team members come from all levels of authority and also include some members who were uninvolved in the event to provide objectivity.\textsuperscript{25-27} For example, at the study institution, cases were assigned to a team that included 4 or 5 orthopedic residents in the third postgraduate year of training, 1 orthopedic faculty member, and 1 nonorthopedic faculty member with experience with the RCA\textsuperscript{2} process. For institutional-level reviews, intradisciplinary teams are convened.

Once orthopedic department teams are formed, the first step in the RCA\textsuperscript{2} process is to create an initial flow diagram that shows the known sequence of events that led to the adverse event (Figure 1). The goal of this diagram is to show what happened and when it happened and to present only the known facts. This diagram ensures that all members have the same basic understanding of what occurred, helps to avoid different interpretations of the same event, and provides a springboard for further investigation.\textsuperscript{27}

Once the initial flow diagram is complete, team members focus on determining what and who contributed to the event. They specifically delineate the steps that led to the close call or adverse event. The Veterans Affairs Health System National Center for Patient Safety created an extensive list of triggering questions for this purpose.\textsuperscript{25,28} Triggering questions provide thought-provoking prompts to identify areas of inquiry or areas of susceptibility that may not have been considered previously. The questions cover communication, training, engineering, equipment, rules, policies, procedures, and barriers. The following are examples of triggering questions: “Was communication between

![Figure 1: Example of an initial flow diagram showing a fictional root cause analysis investigation that is provided for illustrative purposes only. Abbreviations: CT, computed tomography; OR, operating room; post-op, postoperative.](image-url)
staff or organizational layers a factor in this adverse event?” and “Did the design or configuration of the physical environment contribute to the adverse event?” Additionally, the triggering questions spark curiosity and should drive further investigation into relevant documents, environments, and work flows. Triggering questions also help team members to identify which individual or individuals would be most appropriate to help answer each question and provide pertinent details about the event. Appropriate individuals who should be interviewed can include physicians, residents, and mid-level providers as well as nursing, engineering, and ancillary staff. All those interviewed should be asked triggering questions that they reasonably may be able to answer.

The goal of the triggering questions and ensuing interviews is to identify exactly what occurred. This information is used to fill in details of the initial flow diagram to create an event story map that documents the team’s findings by displaying events in chronological order. If done correctly, an event story map conveys in significant detail what happened and when it happened and begins to identify why an event happened. To ensure that the map is comprehensive, it is important to include all relevant supporting details (eg, significant findings, pertinent negatives) (Figure 2). The map must be both comprehensive and clear to allow accurate interpretation by individuals who are not familiar with the adverse event or close call. This map documents what happened for a certain adverse event and can be used to compare what should happen normally and/or what should have happened. The map allows team members to identify where institutional procedures and barriers may have failed or where another barrier should be added to prevent the close call or adverse event from recurring.

To prevent patient adverse events, any work flow should include multiple defensive barriers. Ideally, these barriers should have no weaknesses. However, in practice, defensive barriers have flaws and weaknesses. This approach has been compared with a slice of Swiss cheese. In isolation, a single imperfect barrier—a slice of Swiss cheese—does not prevent errors. However, when barriers work synergistically—slices of cheese are stacked—the odds that an error will occur decrease substantially. However, this does not mean that all error is avoided. A well-done event story map shows occasions or circumstances in which the barriers may have failed—the holes of the Swiss cheese slices lined up. A thorough map can highlight areas of vulnerability where the system can be fortified to prevent errors.

Once the event story map is constructed, a cause and effect diagram is developed. A cause and effect diagram includes a problem statement, an action, and 2 to 3 conditions. These categories address

Figure 2: Example of a completed event story map for an adverse event involving a retained surgical item. The event story map shows a fictional root cause analysis investigation that is provided for illustrative purposes only. Abbreviations: BMI, body mass index; CT, computed tomography; OR, operating room; post-op, postoperative; RCOF, root cause and contributing factor.
communication problems, policies, rules, procedures, and human errors that led to the event. Each causal event box in the diagram is connected to the preceding box by a “caused by” statement.

The critical next step in an RCA² process is identifying what must be addressed to reduce the risk of recurrence. This is done by crafting a statement of root causes and contributing factors. A root cause is the most basic cause that can be identified, when corrected or fixed, eliminates or controls recurrence of an adverse event. A contributing factor is partially responsible for causing an adverse event.²⁵ A statement of root causes and contributing factors is a synthesis of the team’s findings, and the process of formulating this statement should be undertaken only when there is complete understanding of the event, as reflected by a comprehensive event story map and a cause and effect diagram. A clear, concise statement of root causes and contributing factors provides a road map for and justifies the creation of corrective actions that ultimately prevent an error or adverse event.

The process of forming a statement of root causes and contributing factors can be difficult, but to simplify the process, it is beneficial to break the statement into 3 parts: cause, effect, and event. The statement describes how a factor (cause) leads to an occurrence (effect) that increases the likelihood of an undesirable outcome (event).²⁷,²⁸ Once this initial statement is crafted, deeper analysis of the event and identification of effective corrective actions can be achieved with the 5 rules of causation. These rules were first instituted to identify why aviation errors occur; however, they were adapted and refined for health care by the Veterans Affairs Health System (Table 1).²⁸,³² An important consideration is that the cause of the event may not be human error. Use of the 5 rules of causation to craft statements of root causes and contributing factors leads to deeper analysis and identification of the actual root causes.³³

Constructing a statement of root causes and contributing factors distills the team’s findings into a single sentence that states the root cause of the error and identifies what must be fixed. Because an adverse event will likely have more than 1 underlying cause, more than 1 statement may be required. An analysis of RCA² processes performed at the Veterans Affairs Health System between 2001 and 2010 showed that the average number of root causes and contributing factors per RCA² process was 2.1 to 3.6.³³

Appropriately crafting a statement of root causes and contributing factors would be meaningless to patients if it did not lead to action or change. These statements are used to implement specific actions with the goal of sustained systemwide improvement; however, not all actions are equal. Actions can be defined as stronger, intermediate, or weaker, depending on the reliance on human factors. For example, a stronger action eliminates dependence on a human to perform a task correctly. In contrast, a weaker action relies on memory to perform a task correctly. This difference has been called the action hierarchy and has been well defined by the Veterans Affairs National Center for Patient Safety.²⁸,³³ Actions that are developed must be as specific, clear, and concise as possible. In addition, for each statement of root causes and contributing factors, more than 1 action may be required.

A challenging component of the RCA² process is implementing actions and solutions that were identified during the process. The RCA² process requires the backing of institutional or departmental leadership as well as support for proposed actions. If the process is completed correctly and actions are proposed but not implemented, the process is meaningless and participants may become discouraged or cynical toward future RCA² endeavors. Along with leadership involvement, specific individuals must be responsible for implementing each action in a specific time frame. Identifying specific responsible individuals establishes accountability for implementation. Additionally, before implementation of an action, it is important to determine how each action will be evaluated to determine whether it was successful in addressing the identified system. This evaluation can be done by creating a process or outcome measure for each action proposed. A properly crafted process or outcome measure should be specific and quantifiable, with a clear time line for assessment of the effectiveness of the action. This measure should clearly determine whether the action that was implemented resulted in the desired system change.

The RCA² process has numerous steps, and each is vital. There are no shortcuts in this process because each step provides a foundation for the next. At the completion of the process, the team should be able to review the event story map and identify the system’s vulnerability. The statement of root causes and contributing factors should accurately summarize

| Table 1 |
| Five Rules of Causation for a Root Cause or Contributing Factor* |
| 1. Clearly show the cause and effect relationship. |
| 2. Use specific and accurate descriptors for what occurred, rather than negative and vague words. |
| 3. Human errors must have a preceding cause. |
| 4. Violations of procedure are not root causes, but must have a preceding cause. |
| 5. Failure to act is only causal when there is a preexisting duty to act. |
| *Data from National Patient Safety Foundation²⁹ and Wu et al.²² |
what contributed to the vulnerability, and the action proposed should provide a new barrier to prevent recurrence. **Table 2** shows a step-by-step summary of the RCA² process.

**Table 2**

**Summary of the Process of Root Cause Analysis**

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify an adverse event. Promote honest and open reporting of adverse events. Conduct a committee review of clinical documentation to understand the basics of the event. What happened? When? Who was involved? How and why did it happen? Identify appropriate root cause analysis investigations.</td>
</tr>
<tr>
<td>2</td>
<td>Organize a team. Appoint a team of 4 to 6 clinicians, supervisors, and quality improvement experts who have fundamental knowledge of the specific area of interest. Ensure that all team members are treated as equals, even if they have different levels of authority. Ensure that some team members are not directly involved with the case in question. Appoint an unbiased team leader or facilitator.</td>
</tr>
<tr>
<td>3</td>
<td>Develop an initial flow diagram. Use a flow chart to describe the processes that led to the event. Organize the information to reach a mutual understanding of the problem.</td>
</tr>
<tr>
<td>4</td>
<td>Develop an event story map. Use triggering questions to guide further investigation. Conduct thorough interviews with all involved parties. Perform a thorough review of the clinical documentation surrounding the event.</td>
</tr>
<tr>
<td>5</td>
<td>Develop a cause and effect diagram. Write a single problem statement. Identify actions and conditions that caused the problem. Include communication problems, policies, rules, procedures, and human errors that led to the event.</td>
</tr>
<tr>
<td>6</td>
<td>Identify the root causes and contributing factors. Describe how each cause led to an effect and increased the likelihood of an adverse event. Apply the 5 rules of causation to craft a statement about the root causes and contributing factors.</td>
</tr>
<tr>
<td>7</td>
<td>Develop corrective actions. Identify barriers and risk reduction strategies to prevent a recurrence of the root cause. Recognize that multiple actions may be required. Implement a trial of corrective action.</td>
</tr>
<tr>
<td>8</td>
<td>Measure outcomes. Develop outcome measures to ensure appropriate implementation of actions. Track quantifiable data to document the effectiveness of actions over time. Evaluate and fine-tune improvement efforts if needed.</td>
</tr>
<tr>
<td>9</td>
<td>Communicate results. Share the results of the root cause analysis with all staff involved in the event and more broadly if applicable.</td>
</tr>
</tbody>
</table>


**Case Example**

Recently, a RCA² process was conducted for a patient who had peroneal nerve palsy with resultant postoperative foot drop after total knee arthroplasty to correct a valgus deformity. The event occurred early in a new academic year. The RCA² team included 4 postgraduate year 3 residents who were not involved in the care of the patient. The RCA² pro-
cess took 3 months and involved 3 formal meetings with the residents and mentors and 2 other informal meetings of the residents. After an extensive review of the event, the RCA² team identified 2 main root causes and contributing factors. First, multiple verbal signouts led to incomplete transmission of information between the day team and the overnight team. Second, lack of formal training led to confusion about a complex postoperative finding.

These findings led to the suggestion and implementation of 2 actions. The first action was to develop a user-friendly tool in the hospital electronic medical record to facilitate clear and efficient communication among residents. This tool, developed by residents for use only within the orthopedic department, allows for accurate communication between teams. Outcomes were assessed by tracking the use and review of the handoff practice 6 months after implementation. The second action was to develop a week-long intern boot camp to better teach new physicians how to function safely in their new role as well as an intern handbook for use during the orthopedic rotation to supplement the intern’s own knowledge. For each action, an associated person, usually a chief administrative resident, was responsible for monitoring and confirming implementation. Outcomes were assessed by testing for competency before and after the completion of boot camp.

**CONCLUSION**

Elimination of medical errors and promotion of patient safety through quality improvement programs continue to be areas of interest. Payment schemes and national programs have been developed to ensure quality health care. However, few studies have reported on how to develop and implement effective quality improvement programs. This study provides a model for root cause analysis both to instruct orthopedic trainees in patient safety and quality improvement and to produce meaningful changes in patient care. Additional study is needed regarding quality improvement strategies and the development of best practices for effective implementation of the RCA² process.

**REFERENCES**


