DISRUPTED ROUTINES:

EFFECTS OF TEAM LEARNING ON NEW TECHNOLOGY ADAPTATION

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ABSTRACT

This paper reports on a multimethod study of 16 hospitals implementing an innovative technology for cardiac surgery. This inductive study led to propositions about new technology adaptation and how group and organizational characteristics influence this process and its outcomes. The findings reveal substantial differences in how an identical technology was integrated into ongoing practice in a set of structurally homogeneous organizations. A set of factors at the group level of analysis differentiated successful and unsuccessful adopters: characteristics of operating room teams charged with implementing the new technology—team leader behavior, team psychological safety, team learning behavior, and boundary spanning—were associated with successful adoption. Team membership stability was associated with the rate of efficiency improvement using the new technology. Organizational factors, such as size, type (academic versus community hospital) and organizational support for and experience with innovation, were not associated with either outcome. We develop new theoretical propositions, and suggest that team learning may moderate the strong relationship between structure and technology adaptation.

Adopting new technologies is essential to sustained competitiveness for many organizations. In both manufacturing and service industries, new technology can lead to product and process improvements that produce tangible market advantages—but these advantages can be elusive. Organizational research suggests that failure to adopt innovations, even those with demonstrable benefits, is commonplace (e.g., Henderson and Clark, 1990; Tushman and Anderson, 1986). Organizations have been depicted as blind to the existence or advantage of external innovations (March and Simon, 1958), trapped by current competencies (Levitt and March, 1988) and business models (Christensen, 1997), paralyzed by core rigidities (Leonard-Barton, 1992) and handicapped by a lack of relevant expertise (Cohen and Levinthal, 1990)—all leading to a failure to adapt in the face of environmental changes. Understanding when and why innovations are adopted has been the subject of considerable research. Much of the focus in this literature has been on the decision to adopt, investigating the timing of adoption decisions, product features that promote adoption (e.g., Rogers, 1983) and organizational characteristics that facilitate recognition of the significance of an innovation (Iansiti and Clark, 1994; Cohen and Levinthal, 1990). Researchers have suggested that an organization's history of innovation and the sophistication of its own research activities can allow it to adopt future innovations more easily, through building absorptive capacity (Cohen and Levinthal, 1990). An implication of much of this research is that the management challenge lies in ensuring awareness of innovations and commitment of resources to them. With some exceptions (e.g., Leonard-Barton, 1988), this literature has paid less attention to understanding the conditions under which organizations successfully integrate new technologies into their operations. The decision to adopt may be only a first—and often far from sufficient—step in integrating a new technology into the ongoing work of the organization and obtaining benefits from its routine use. Often, both the technology and the organization must adapt for adoption to succeed (Leonard-Barton, 1988).

When new technologies disrupt well-established organizational routines, they are likely to be particularly difficult to implement. Another stream of research focusing on the ways in which behavioral routines and roles can be threatened and disrupted by the introduction of new technologies has used ethnographic methods to develop rich portraits of new technology implementation (e.g., Barley, 1986; Orlikowski and Hofman, 1997). From detailed investigations of work activities, these studies show that organizational adaptation to new technologies does not always proceed as planned and, instead, is fragmented and episodic (Orlikowski and Hofman, 1997; Tyre and Orlikowski, 1994). Also, organizational structures, such as patterns of interaction between different functions or role occupants, can be altered by new technology, sometimes in different ways in similar organizations (Barley, 1986). Structure consists of power dependencies and contextual constraints (Weick, 1993; Ranson, Hinings, and Greenwood, 1980); technology describes equipment that shapes and constrains tasks (Galbraith, 1974). Current structuration theory maintains that structure and technology exert a reciprocal influence, such that adaptation does occur, albeit slowly, constrained by existing status relationships (Barley, 1986). Further, organization members' beliefs about the meaning of a new technology may affect its acceptance in the organization; for example, information technology can be seen as automating jobs or as informing intelligent users to do their jobs, leading to differences in user acceptance (Zuboff, 1988). For these reasons, after the decision to adopt a new technology has been made, implementation still may be difficult and unpredictable. In general, this stream of research focuses on the organizational and human experience during new technology adaptation rather than on explaining differences across organizations implementing the same technology.

Theories of organizational learning suggest that some organizations are more able to learn than others (Senge, 1990; Garvin, 2000), which may include making changes required for successful adoption of new technologies that threaten organizational routines. Despite compelling theory, empirical studies investigating differences in organizational learning processes and outcomes are rare. Many studies are limited to single organizations (e.g., Kim, 1993; Roth and Kleiner, 2000; Argyris, 1993). Organizational learning research has not collected data from a number of organizations simultaneously facing a similar opportunity for adaptation to investigate factors promoting an effective transition process.

In this paper, we build on the organizational learning literature by investigating how cardiac surgery departments learn to use to a specific new technology. We frame adaptation to new technology as a collective learning process. Adoption starts with the decision to try a new technology, but successful adoption often requires adaptation, or organizational changes, to enable its use. Because little is known about factors affecting this learning process, our aim is to develop new theory and suggest propositions for future research, rather than to test hypotheses. We studied 16 hospitals and used multiple methods to investigate both group- and organization-level factors that might affect outcomes. Not all hospitals conduct cardiac surgery, but those that do share a powerful institutional context.

INSTITUTIONAL STRUCTURE AND TECHNOLOGY IN CARDIAC SURGERY

Across hospitals of varying size, location, history, and academic status, the structure and process of cardiac surgery—especially as manifested in roles and relationships in the operating room team—are remarkably consistent. Performing a coronary artery bypass graft (CABG) or valve replacement surgery includes many small adjustments and minor differences across procedures due to patient variation and surgeons' preferences, but overall these procedures are highly routine, involving the repetition of a precise set of moves in operation after operation. The role of each operating room (OR) team member is well understood and prescribed. Anesthesiologists put the patient to sleep and monitor vital functions during surgery; surgeons perform the actual surgical procedures (cutting and stitching), monitor the patient's well-being and oversee the team; perfusionists are technicians who run the heart-lung bypass machine, and scrub and circulating nurses prepare equipment and support the surgeon in a variety of ways.

These team routines transcend institutions. Although medical practices may vary across hospitals, professional training in surgery follows widely accepted protocols and utilizes standard technology—both derived from the research literature with which physicians and medical centers are expected to remain current. This promotes homogeneity across hospitals. Moreover, cardiac surgery places even more value on standardization than other surgical specialties; the only variation typically found involves specific surgical techniques and details of the layout of the operating room (O'Connor et al., 1996). Acting within prescribed roles, team members are able to act in perfect concert without discussion; conversation that does occur is typically about an unrelated subject, such as last night's baseball game. As an informant in our study explained, "In [CABG surgery], you look at the surgeon and you know the body language, and you act." The operating room team in a typical cardiac surgery department is likely to perform one or two, and sometimes three, open-heart operations each day and, therefore, hundreds each year. All members of the surgical department are assumed to be equally capable of doing the work of their particular discipline, and team members within a discipline are readily substituted for each other. This consistency of practice made it an ideal context in which to seek differences in patterns of new technology adaptation.

The Cardiac Surgery Task

Conventional cardiac surgical procedures are divided into three phases. First, the surgeon carries out a median sternotomy (cutting open the chest and splitting apart the breastbone) and stops the heart. The surgeon then directs the nurse and perfusionist to connect the patient to a heart-lung bypass machine to regulate oxygenation and support blood pressure while the heart is stopped. In the second phase, the surgeon repairs and replaces diseased components ("stitching"), and in the third phase, the surgeon re-starts the heart and the patient is weaned from the bypass machine. The division of task responsibilities in the OR team mirrors powerful hierarchical status relationships in cardiac surgery. This hierarchy is further reinforced by the formal and informal status relationships between doctors and nurses in medicine overall, as well as by the formal medical and legal accountability of doctors.

A New Technology: Minimally Invasive Cardiac Surgery

Minimally invasive cardiac surgery (MICS), an innovation developed and manufactured by a device company called Minimally Invasive Surgical Associates (MISA), differs from the conventional approach in that the breastbone is not split apart.[1] This reduces the extent of pain and recovery time for patients,

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[1] All names are pseudonyms.

such that they are able to resume normal activities more quickly than after conventional cardiac surgery. Using special new equipment, the heart is accessed through small incisions between the ribs, and the patient is connected to the bypass machine through the artery and vein in the groin. A deflated "balloon"—threaded into the aorta and then inflated to prevent blood from flowing backwards into the stopped heart—replaces the traditional clamp inserted directly into the chest. This placement requires coordination among all team members; the balloon's path must be carefully monitored with ultrasound technology (trans-esophogial echo, or "echo") because there is no direct visual and tactile data to help guide the process.[2] The tolerances on balloon location are excruciatingly low, and correct placement is critical. Unlike conventional surgery, in which surgeons receive information from direct sensation, MICS calls for team members to supply the surgeon with vital information displayed on digital and visual monitors. Once the balloon clamp is in place, team members must continue to monitor to make sure it stays in place. The improvements for patients promised by the technology come at a high learning cost for surgeons and OR teams. As one surgeon we interviewed joked, "[MICS] represents a transfer of pain—from the patient to the surgeon."

The new technology not only changes individual team members' tasks, it dramatically increases team interdependence. The anesthesiologist and perfusionist now must work closely together to regulate blood pressure, the surgeon and the anesthesiologist must coordinate to monitor the position of the balloon clamp, and all team members must coordinate to monitor the patient's vital pressures. The new technology thus disrupts a well established OR team routine and requires new communication patterns. Successfully enacting this change affects deeply engrained status relationships in the OR team, as the surgeon's role shifts from that of an order giver to a team member in an interdependent process. As a nurse we interviewed explained,

> When you're on bypass for the standard CABG, there's no need for communication at all. In MICS there's a lot more. The pressures have to be monitored on the balloon constantly. For putting in the balloon and the primary line, the communication with perfusion is critical. It is totally different. When I read the training manual, I couldn't believe it. It was so different from standard cases.

[2] Trans-esophogial echo (TEE) is a kind of ultrasound technology primarily used in cardiology.

with physicians acting as order givers. Technicians' subordinate status thus was maintained at Urban; interdependence and reciprocal negotiation of knowledge did not increase, resulting in frustration and slow progress. Even when Urban physicians later began to ask for help from technicians, their requests were for technical knowledge only (related to equipment function), not for clinical knowledge, in contrast to what happened at Suburban. Barley attributed this difference to several factors, especially the presence of relatively less experienced radiologists and more experienced technicians at Suburban. The present study builds on this earlier research by investigating multiple factors that might influence these kinds of differences in responding to a new technology.

Because the institutional context and the technology in conventional cardiac surgery are mutually supportive and reinforcing, this context—especially its status structures—presented a powerful barrier to the introduction of a new technology that required more interdependence. As Barley found, it is possible that this barrier is more difficult to overcome in some hospitals than in others, due to organizational or team characteristics. Organizational factors such as past experience with innovation in an organization (Cohen and Levinthal, 1990) and seniority of those introducing a new technology (Barley, 1986) can influence adoption outcomes. Although team factors have not been investigated in this context, research has shown that teams learning a new task are more likely to improve coordination and efficiency when they train as teams and stay together for subsequent task execution than when they change their membership (e.g., Moreland et al., 1998; Foushee et al, 1986). Thus, drawing from theories of team effectiveness (Hackman, 1987), we speculate that OR teams with stable membership may achieve efficiency in learning new techniques more quickly than unstable teams and that this may lead to adoption success. Further, team psychological safety—a shared belief that the team is safe for interpersonal risks (Edmondson, 1999)—may affect a team's ability to engage in the new behaviors required for MICS, overcoming institutional barriers described above. Thus, we consider both group and organizational factors. The research question guiding the study was what differentiates organizations that learn —successfully incorporating the new technology into ongoing routines—from those that fail to learn.

METHODS

Research Design

We used an embedded multiple case design (Eisenhardt, 1989; Yin, 1989) and multiple methods to investigate 16 cardiac surgery organizations implementing minimally invasive cardiac surgery. Each case encompassed data on organizational factors, team factors, individual surgical procedures, and learning outcomes. Throughout site visits and data analysis, we were blind to hospital identity in the outcome data set so that our perceptions of sites would not be influenced by this knowledge. After identifying salient variables in the case studies, we investigated relationships between organizational and team factors and learning outcomes.

Sample. We selected 16 sites from a population of 150 U.S. hospitals that had purchased the technology at the time of this study, in early 1998. Our sample satisfied several criteria—representing the population (through inclusion of both academic and community hospitals of varying size and location throughout the U.S.), temporal comparability (adoption of the technology within the first year), and willingness to participate in the study. Participation involved one to two days of interviews as well as allowing us access to clinical data from all procedures conducted with MICS. All sites were well-respected cardiac surgery departments in the U.S., minimizing differences in industry context that could be confounded with other factors in building a theory of adaptation to new technology. They ranged in size from 400 to 3700 (with a median of 1250) cardiac operations per year, 3-14 surgeons (median=8), and 15-110 total operating room personnel (median=42). Each hospital had only one OR team involved in implementing MICS. Our sample of 16 was larger than needed to reach theoretical saturation (Eisenhardt, 1989).[3] Although using this larger sample required more field visits, it allowed exploratory quantitative analyses of relationships between independent and dependent variables. It also allowed us to develop confidence in our understanding of how U.S. hospitals were responding to the technology; for example, after 16 site visits, we could conclude that factors that were consistent across all sites were unlikely to have been replicated by chance. Table 1 provides characteristics of the sample.

Table 1 about here

Data Collection

Phase 1. To familiarize ourselves with the technology and the surgical process, we conducted initial field research at MISA. Next, we attended MISA's three-day training program, accompanying an operating room team from a hospital we planned to study throughout its implementation process.[4] During the training program, we attended the lectures and observed team members as they went through hands-on laboratory sessions. We also interviewed team members about how they perceived the technology and the implementation challenge. We then developed a structured interview protocol to assess organizational and team characteristics that might influence adoption success and to create systematic measures of a consistent set of variables across sites. As little was known at the outset about how OR teams adopt new technology or new routines, we developed the protocol iteratively, as we learned more about the phenomenon. We modified the instrument slightly after each of the first few site visits, developing new questions for issues that emerged as salient. To minimize missing data, we re-contacted initial hospitals to ask questions added later. The final instrument had 41 questions, most with structured

[3]After about 10 site visits, we began to sense that we had seen the full range of variation in MICS implementation, a suspicion that was not later disconfirmed.
[4] Ultimately, we were not able to study this team further as it had not yet done a first MICS case a year later. However, we recruited a second team at the training session, "Saints Hospital," to join the study.

responses (visible only to interviewers) and a few unstructured questions such as "Can you tell us how MICS got started at this hospital and how it's going?" and "How is this hospital different from other hospitals?" Certain issues were addressed by two or three related questions, to develop more robust constructs than allowed by a single question. Interview questions are shown in the Appendix.

Phase 2. The three authors and a research assistant conducted 165 interviews at 16 hospitals over a five-month period. All four of us participated in the first four site visits, to promote consistency in using the protocol and recording data; a team of two to three researchers visited each remaining site. Our different disciplines—organizational behavior, medicine and economics—led us to focus on different phenomena, leading to a more comprehensive understanding of the implementation process than any of us could have developed alone. For example, those of us who were not physicians initially had difficulty understanding the medical issues and technical language; in the process of collecting data, however, we learned from each other and became better able to listen for the kinds of data originally heard only by specialists in each discipline.

At each site, we interviewed all members of the operating room team and other hospital personnel who interacted with team members or were knowledgeable about MICS. We conducted 7 to 12 interviews, with an average of 9.9, per site. Team members interviewed consisted of one to three people in each of four roles: surgeons, anesthesiologists, OR nurses and perfusionists. Others interviewed included hospital administrators, cardiologists, intensive care unit (ICU) nurses and general care unit (or floor) nurses. Interviews typically lasted an hour but ranged from 30 to 90 minutes. We started each interview with the open-ended question asking informants to describe how MICS was going, to obtain perceptions of what mattered before influencing them with specific questions. Multiple informants at each site were used both to obtain different perspectives across roles and to promote the validity of our data by cross checking responses about factual issues.

Informants' responses to questions were coded using scaled or categorical responses developed in the first few site visits as we learned the nature and range of differences across sites. Each interviewer circled one of the responses and took supporting notes to capture details of informants' answers. We also took extensive notes to capture responses to open-ended questions, annotated these notes to clarify potential ambiguities within the same day, and later transcribed them to capture informants' verbatim responses as closely as possible. After each site visit, we met as a research team to review our coded responses. In almost all cases, interviewers had selected a common rating. The few discrepancies were resolved by discussion, citing evidence from multiple interviews capturing responses to the same question. This process generated a single rating or categorization for each question for each hospital, and allowed us to create a quantitative database with scores for each variable for each hospital.

Data Analyses

We analyzed our data to support two aims: first, to deeply understand the implementation process for this technology and, second, to identify factors that might differentiate successful adopters from others.[5] We developed propositions about factors that facilitated implementation, drawing initially from views espoused by informants and investigating whether similar views and factors emerged at subsequent sites (Eisenhardt, 1989). We wrote case studies to capture details of each site and facilitate comparison across sites. Several themes emerged, including how the implementation process was managed, the extent to which the OR teams were able to change their behaviors in the operating room, and how they communicated with other clinical groups. After field visits were completed, we conducted further analysis of structured and unstructured interview data.

Structured interview data. To consolidate the coded data generated by the interviews into meaningful

[5] The goal of this study was to explore factors influencing *adoption success* and not clinical effectiveness of MICS. However, we did conduct several analyses to ensure consistency across sites in effectiveness in using the technology: first, we checked complication rates and mortality rates and found no differences across sites. Second, the overall mortality rate in our sample (1.5%) was lower than the mortality rate for standard cardiac surgery (2-2.5%), which does not suggest that patients are better off with MICS but more likely that surgeons were conservative in their use of the new technology. Further speculation about clinical outcomes is beyond the scope of this study.

variables, we first examined the correlation between variables assessing a similar construct (Campbell and Fiske, 1959). For example, two coded questions addressed the hospital's "dry run" the night before the first case—one related to inclusiveness of team participation and the other to comprehensiveness of content discussed in the session. These were highly correlated ($r = .93$, $p<.001$) and together make up a construct we call *team preparation.* We then assessed internal consistency reliability and discriminant validity for all composite variables (see Table 2). Together, these analyses supported the creation of five new variables, listed in Table 2, including *team preparation* and *boundary spanning.* Detailed descriptions of all quantitative measures are found in the Appendix.

Table 2 about here

Unstructured qualitative data. A research assistant who had not participated in site visits sorted the transcribed data into seven major categories identified by the authors; these categories correspond closely to categories built into the interview protocol, such that the relevance of a given quote to a major category was generally unambiguous. Data that fit into more than one major category, such as a quote relevant to both "Leadership" and "OR Team," were given multiple codes. The research assistant then developed subcategories by identifying recurring themes within each category, listed in Table 3, and finally coded each data unit (ranging from one to several sentences) according to major and minor categories, speaker profession, and hospital. The coded data set allowed us to quickly compare particular features across hospitals by excerpting all data in the category of interest, sorted by hospital, facilitating cross-case analyses in an otherwise unwieldy qualitative data set. It also allowed us to develop quantitative measures to assess two constructs that surfaced as important themes—OR team members' perceptions about the *ease of speaking up* and *team leader coaching*. Two research assistants independently rated quotes coded as relevant to ease of speaking up on a three-point scale, using anchors we developed together. (See Appendix). This provided a second measure of psychological safety, independent of the interviewers' rating, allowing triangulation for this subjective construct. Second, they used a three-point scale to rate quotes coded as related to team leader coaching. To avoid biases, we used raters who did not participate in the field research and quotes were rated knowing the profession of the speaker (providing context needed to interpret their meaning) but without knowing which hospital he or she was from. At the individual-quote level of analysis, interrater reliability was high for both measures (Spearman Brown up, R = .89 and .85, respectively (Rosenthal and Rosnow, 1991)). One-way ANOVA showed that ratings of quotes were similar within and varied significantly between hospitals, confirming the consistency of informants' perceptions of each site and allowing aggregation to group-level measures (See Appendix). Lastly, ease of speaking up was significantly correlated with psychological safety as measured by the interviewers' ratings of informants responses (r =.80, p<.001).

Table 3 about here

Archival clinical data. We obtained data documenting clinical detail on all 669 operations conducted in the first six months of using MICS at the 16 hospitals. These data were provided to MISA by every hospital using the new technology; we were given a small subset of this data set, covering only the sites in our sample, each of which agreed to give us this access.[6] All patient identifiers had been removed from the data set. The resulting data allowed us to calculate the rate of procedure time improvement, controlling for cumulative number of MICS cases and for relevant clinical variables such as type of procedure and patient health factors. This analysis produced a measure of *efficiency improvement*, based on the percent reduction in time for each successive operation for each hospital. (See Appendix for the model.) Second, from each hospital, we collected data on the annual number of cardiac surgery operations. Using this and the clinical data, we calculated an *adoption success* index—following Iansiti and Clark (1994)—as the sum of the ranks of three variables: (1) the number of MICS cases conducted in the first six months at each site, (2) the percent of heart operations conducted using MICS in the same period, and (3) whether a site was increasing, decreasing, or remaining steady in its use of MICS. The measure considered absolute volume, penetration levels and trend, thereby giving credit to several dimensions of adoption success and not unduly penalizing small centers for carrying out fewer MICS operations. We formulated this index in advance of analyzing the interview data.

[6] MISA collected these data from all hospitals using MICS. After completing site visits, we discovered gaps in the data set and a research assistant obtained missing data directly from the hospitals in our study.

Analysis of relationships across variables and data sources. Given the small sample size and the nature of our rating systems, we utilized a non-parametric statistical test, Spearman's rho, to conduct exploratory tests of relationships between variables. Nonparametric statistics are inferential tests that do not require assumptions about the distribution of the population from which the samples were taken, and Spearman's rho is particularly well suited to small samples and to interval-scaled data for which the distribution is not necessarily normal (Saslow, 1982). Although Pearson's r can inflate the degree of association between two variables of this kind if there are a few extreme values, Spearman's rho solves this problem by correlating the rank order between two variables. This test of association was used to support theory development by providing insight into which relationships suggest promising avenues for future research, rather than to test hypotheses.

GROUP AND ORGANIZATIONAL INFLUENCES ON NEW TECHNOLOGY ADAPTATION

Prior research has suggested that organizational structures limit an organization's ability to adopt new technologies that disrupt existing routines and relationships. This perspective implies that structure shapes the outcome of new technology initiatives and that, when re-structuring does occur, it is emergent and incremental. The data from this study suggest a different view. Although organizational and status structures in cardiac surgery presented a powerful barrier to implementing MICS, we found that some hospitals successfully integrated the new technology into ongoing practice. One hospital in the sample expanded its use of MICS to encompass 95% of its cardiac valve operations, while, at the other extreme, a hospital had conducted only a handful of procedures and its use of the new technology was declining.

To explain these different outcomes, we examined factors that varied across successful and unsuccessful adopters. Qualitative and quantitative data related to team leader behavior, team psychological safety, team learning behavior and boundary spanning revealed striking differences between the seven most and seven least successful adopters.[7] In contrast, other factors, such as hospital type, history of innovation, and status of the adopting surgeon, did not vary with either outcome. Several theoretical propositions are suggested by these analyses.

Effects of Team Leader Behavior

Major organizational change has been said to be facilitated by a leader providing both a rationale for changing and coaching on how to change (e.g., Kotter, 1996). Although this premise has not been explored in the context of technology implementation, team leader behavior in the face-to-face context of task execution may influence how people perceive and respond to a new technology, thus affecting how well it is integrated into an organization. In these data, the behavior of the adopting surgeon, as the team leader, appeared to be an important influence on how OR teams responded to MICS. In this section, we explore this relationship using a subset of four of the 16 cases and then turn to quantitative data from the full sample. Focusing on a subset allows us to illustrate contrasts in a small number of sites that will become increasingly familiar to the reader, facilitating repeated comparisons. To do this, we selected four hospitals that are representative of the sample: half are academic, half are community, and adoption success varied independently of hospital type as it did in the full sample (rho = -.29, N=16, p=.28).[8] We start with Chelsea and Janus—two similar metropolitan teaching hospitals that achieved different outcomes, and adopting surgeons took different approaches to implementation. Next, we turn to Decorum and Mountain, two similar provincial community hospitals that also had striking differences in both team leader behavior and outcome.

A top-down approach: Chelsea Hospital. The adopting surgeon at Chelsea, whom we call Dr. C (for Chelsea) was nationally renowned and recently recruited to run and help revitalize the cardiac surgery department. He had significant prior experience with MICS, having performed 60 procedures at another

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[7] In looking at the most and least successful adopters, we ignore the two middle cases, to reflect the location of step changes in the success index and to avoid making an arbitrary distinction between two adjacent sites in the middle.

[8] All p-values are two-tailed.

hospital (not in our sample) and worked on the early design of the technology as a scientific advisor to MISA. Chelsea administrators were supportive of Dr. C's request to invest in MICS and agreed to send a team to the MISA training program prior to the start of his appointment. The surgeon thus played no role in configuring the team, which was put together according to seniority and consisted of the heads of anesthesiology, perfusion and cardiac surgery nursing. Dr. C did not participate in the team’s "dry run" prior to the first case; he explained that he did not see MICS as particularly challenging —having been experimenting with placing a balloon in the aorta since 1992— and that "the technical aspects are not much," so "it was not a matter of training myself, it was a matter of training the team." Dr. C did not recognize a need for a change in his style of communication with others in the team, explaining, "once you get the team set up, I never look up [from the operative field]. It's they who have to make sure that everything is flowing." He also did not utilize aids such as wearing a head camera to help the team monitor patient information. An OR nurse, Martha, noted that "[Dr. C] can visualize [the operation] without it," but she could not, and so "the most difficult thing about MICS is that you can't see. If there is a bleeding artery or something unusual, I can't see it. In an open chest I can see." Finally, the surgeon did no active coaching with the team as MICS was being introduced. As one team member noted, the surgeon's expectation was that "they know what is going on."

A team challenge: Janus Medical Center. Like Chelsea, Janus had a history of adopting surgical innovations. Disappointed in the performance of an earlier innovation he had tried, the chief of cardiac surgery, Dr. J, was eager to test MICS. In contrast to what happened at Chelsea, his first step was to put together a special OR team. After selecting a second surgeon, who would be particularly suited to "manage data collection," he deferred to leaders in each of the other three disciplines to select the remaining six team members. Each group selected carefully. For example, Betty, the head of cardiac surgical nursing, selected herself and another highly experienced nurse to participate, because of the challenge of the new procedure. The second nurse, Sophia, reported being selected because "the surgeons recognize how important our knowledge is." Similarly, the head anesthesiologist explained, "the key to success [in MICS] is finding people who are good at what they do and limiting the technique to those people... the technique is so challenging that I felt it was best to keep in the hands of a couple of people." Interestingly, the composition of this team resembled Chelsea's in that both were characterized by seniority; however, perceptions of the selection process were strikingly different. Unlike team members at Janus, no one at Chelsea reported being selected for particular skills.

By focusing on patient benefits and the desire to be a leading cardiac center, Dr. J motivated the team to endure the hardship that learning MICS entailed. He communicated in a thoughtful manner to help all members of the team understand intricacies of the new procedure. Betty reported that "[the surgeon] talks everyone through [the procedure]. He says things like 'can you see it?' and so on." He frequently communicated his growing confidence in the technology, and all team members shared a belief that patients benefited enormously from the procedure. Sophia enthused, "Every time we are going to do a [MICS] procedure I feel like I've been enlightened. I can see these patients doing so well. ...It is such a rewarding experience. I am so grateful I was picked." This enthusiasm—almost evangelical praise—cannot be attributed to ease or enjoyment in doing the procedure. In fact, team members complained bitterly about the hours of wearing a lead apron required for protection against the fluoroscopic radiation used in MICS. Nonetheless, motivation for continuing was high, and team members saw the minimally invasive approach as part of cardiac surgery's future.

Business as usual: Decorum Hospital. Dr. D, the chief of cardiac surgery at Decorum—a community hospital within driving distance of two large cities—decided to adopt MICS, because, as he explained, "We'd like everyone to know we can do it. It is a marketing thing. Patients want to know we can do it." He continued, "we try to be innovative here." Other team members believed that Dr. D's reason for doing MICS was solely for image: A nurse explained, "He wanted to be competitive with other institutions. For example, [large city] is so close, we need to be at the leading edge," and another later echoed, "to keep up with the Joneses." This defensive stance accompanied a practice that was unique in our data set—of using the new technology while carrying out a small median sternotomy—meaning that the surgeon continued to split open the patient's breastbone, albeit using a smaller incision than usual. According to Jack, one of the perfusionists, this was seen as a more safe practice than MISA's recommended approach, even though "every time I go to a conference, it doesn't seem like we are doing it like MISA says—but having the stenotomy makes the access safer for [patients] so [we don't] take any risks." A nurse presented this slightly differently, "[the surgeon] is a creature of habit. He always does the median sternotomy." Another nurse, Pat, described his leadership style as follows: "Dr. D is very regimented. Proper decorum in the room is his big thing." We were told in two different interviews that the surgeon was the "captain of the ship" and in one that "he's the chairman and that's how he runs the show." He did little coaching and was difficult to approach; Pat explained that "[to speak to the surgeons] you have to go through formal channels." Amidst this formal structure, the surgeon insisted that team members who participated in the training remain the only people doing MICS, to enable them to learn the procedure effectively.

An innovation project: Mountain Medical Center. The MICS team leader at Mountain—a community hospital serving a small city and the surrounding rural area—was a junior surgeon who recently joined the cardiac surgery group. Although the hospital did not have a history of extensive innovation, the most senior cardiac surgeon—dissatisfied with what he knew of previous minimally invasive technologies—suggested that the new surgeon, Dr. M, take the lead in evaluating and potentially adopting MICS. More than in any other site in our sample, this young surgeon treated implementation of MICS as a project that needed to be structured and led. His leadership took two forms: managing a project and empowering a well-selected team. He recognized that MICS represented a paradigm shift for the surgeon and the rest of the OR team, and explained:

> The ability of the surgeon to allow himself to become a partner, not a dictator, is critical. For example, you really do have to change what you're doing based on a suggestion from someone else on the team. This is a complete restructuring of the OR and how it works. You still need someone in charge, but it is so different.

Dr. M explained that his own behavior had to shift from order giver to team member and that he worked to empower and inspire other team members. One of the perfusionists reported, "the surgeon empowered the team. That's why I'm so excited about MICS. It has been a model, not just for this hospital but for cardiac surgery. It is about what a group of people can do." He explained that it works because "the surgeon said, 'hey, you guys have got to make this thing work.' That's a great motivator." Dr. M often wore a head camera, as a nurse explained, "so others can see what's going on, and ask 'why did you do this then?'" As a result of this effort, team members noted that communication was "much more intensive" and that the "hierarchy [has] changed" so that "there's a free and open environment with input from everybody." Finally, Dr. M mandated stability of the OR team and the surgical procedure for early cases. The team that went to training performed the first 15 cases without adding or substituting any members. Also, he deliberately scheduled early MICS cases closely together enabling the team to perform six in its first week, compared to one or two for most hospitals. Third, he selected similar patient conditions for the first 30 cases to keep the surgical procedure stable. After this period, the team began to innovate and even developed suggestions for modifications in the equipment, which they communicated back to MISA and the perfusionists worked with another manufacturer to design a custom perfusion pack for MICS.

Team leader behavior and adoption success. The adopting surgeons at Janus and Mountain actively coached the OR team and managed implementation carefully. In contrast, at Chelsea and Decorum, the surgeons did not design or manage implementation as a project, nor did they coach other team members, viewing MICS as more of a technical challenge for surgeons than a team learning challenge. The former two sites were 5th and 2nd of 16, respectively, in adoption success, and the latter two were 10th and 16th. Table 4 summarizes characteristics of the four hospitals. To build on these comparisons, we examined the correlation between measures of team leader coaching behavior (from rated qualitative data) and adoption success (from archival data) for all 16 sites and found a significant positive relationship (rho=.65, p<.01). Surgeon status in the organization—whether he was department head or a junior surgeon—was unrelated to adoption success.

Proposition 1: Team leader coaching fosters successful adoption of new technology.

Table 4 about here

Effects of Team Psychological Safety

Past research suggests that psychological safety promotes learning behavior in work teams (Edmondson, 1999) but teams implementing new technology have not been investigated. Informants in our sample uniformly described a need to engage in new and historically threatening behavior if the OR team was to succeed with MICS. It is likely that members of OR teams with psychological safety—especially team members in lower status roles—will have an easier time making this change than those lacking in this dimension. Although the MISA training emphasized the need for everyone in the team to speak up with observations, concerns, and questions during an MICS operation, we found that team members' perceptions of the safety of the interpersonal climate in their own team for this kind of behavior varied widely across sites. Thus, psychological safety—as manifested by informants' expressions of how easy or difficult it was to speak up in the team—seemed to matter greatly in terms of whether or not OR teams could change their behavior as MISA suggested. Not surprisingly, given the explicitly hierarchical context of the operating room, team leader coaching appeared to be an important influence on this, and—consistent with this observation—team leader coaching (rater's measure) was correlated with psychological safety as assessed by both interviewers (rho=.82, $p<.001$) and raters (rho=.65, $p<.01$).

Our interviews with team members suggested strongly that psychological safety varied across teams, and, further, members of the same team presented a consistent view of how easy or difficult it was to speak up in their team. At Chelsea, where Dr. C discouraged communication in the OR, team members reported being uncomfortable speaking up about problems during operations, and Martha reported, "if you observe something that might be a problem you are obligated to speak up, but you choose your time. I will work around him. I will go through his PA [physician's assistant] if there is a problem." In contrast, at Janus, Betty said, "I am very comfortable speaking up. …You have to talk. I have no qualms about it. In a regular case, you can clam up, but it's too late in MICS. There is no chance for recovery." In equating no qualms about speaking up with no chance for recovery, she reveals a tacit belief that the potential value of an observation enables one to feel comfortable speaking up—against status barriers and historical precedent.

Team members at Mountain also reported being comfortable speaking up. For example, an anesthesiologist at Mountain said, "I prefer working with [Dr. M] over the other surgeons because I can talk about anything with him." An OR nurse also claimed that "[Dr. M] is a nice guy really; we have a really good working relationship. I can talk to him about anything in the operating room. He is willing to stop to talk." In contrast, a Decorum nurse said, "In Dr. D's room, he doesn't want unnecessary chatter. Period." Similarly, Jack, the perfusionist, offered an example of a time when he immediately spoke up about a problem during the procedure:

> For example, once when we were having trouble with the venous return, and I mentioned it, the surgeon said, 'Jack, is that you?' I said yes. He said, 'are you pumping[9] this case?' I said 'no I'm assisting.' 'Well in the future, if you are not pumping the case, I don't want to hear from you.' You see it's a very structured communication.

He laughed, apparently aware of how absurd the surgeon's response must sound, given that he had pointed out a potentially life-threatening problem. Consistent with this picture, a nurse told us that it was difficult to speak up openly when she suspected that something might be wrong, such as a possible migration of the balloon clamp (also life-threatening):

> I'd tell the adjunct. Or I might whisper to the anesthesiologist, "does it look like it migrated?" In fact I've seen that happen. It drives me crazy. They are talking about it—the adjunct is whispering to the anesthesiologist, "It looks like it moved" or "There is a leak in the ASD" or something, and I'm saying "You've got to tell him! Why don't you tell him?"' But they're not used to saying anything. They are afraid to speak out. But for this procedure you have to say stuff.

To fully understand this description, it is useful to visualize the constrained quarters of an operating room, to realize that speaking up such that everyone hears you is virtually a default option. It requires effort to whisper to only one person, hoping to have the information passed along in that way. Moreover, the nurse's belief that team members "are afraid to speak out" epitomizes an absence of team psychological safety (Edmondson, 1999). Finally, in the full sample, there was an association between psychological safety and successful adoption. Quantitative data showed that both measures (interviewers' and raters') were correlated with adoption success (rho=.60, p<.05 and .47, p=.06, respectively).

Proposition 2: Team leader coaching promotes team psychological safety, which facilitates behavior changes needed for successful adoption of new technologies that disrupt organization routines.

Effects of Team Learning Behavior

We proposed above that team leader coaching behavior fosters adoption success; here we examine a core mechanism—the behavior of the team implementing the technology—through which a team leader might influence this outcome. In cardiac surgery, the surgeon is in the best position to facilitate an OR team in trying new behaviors that allow MICS to take hold. The data suggested several team learning behaviors were associated with adoption success. These are preparation as a team prior to using the technology with a first patient, adapting communication in the OR to the demands of the new procedure, and introducing process innovations. The extent to which OR teams engaged in these behaviors varied across sites.

Team preparation. All teams were encouraged to get together following formal training at MISA for a dry run to practice the new procedure. Taking this opportunity seriously as an OR team is likely to promote successful adoption, because a careful practice session is likely to establish a foundation for open communication and teamwork. Across the 16 hospitals, we observed considerable variation in the extent of team preparation prior to the first MICS case. At some hospitals, team members deliberately planned changes for the new procedure. An OR nurse at Mountain reported that the team got the instruments ready and wrote up "new protocol sheets for every group... we talked about how the communication would be important, and everyone was involved in [this] conversation, nurses, surgeons, everyone. We developed special trays, more customized, more streamlined, for MICS." In contrast, other teams took minimal steps to prepare as a team prior to the first procedure. At Chelsea, nurses conducted a dry run of the procedure on their own; the surgeon did not attend, and other team members prepared individually by reading the manual. Similarly, despite the surgeon's attention to coaching in general, the Janus OR team

[9] Pumping, in this context, meant being "first" rather than "second" or assisting perfusionist.

practiced without the full team; as one anesthesiologist noted, "[We did] one dry run the afternoon before. I don’t even think the surgeon showed up." The Decorum team was among those that prepared the least. When asked if he did anything to prepare for the first procedure, the surgeon at Decorum said, "Not really. Extensive background reading of course. I felt well prepared. A little trepidation but ready to go." A nurse confirmed this lack of team preparation: "[We] kind of more or less looked at the room."

Change in team communication. MICS required that team members communicate and interact in different, more interdependent ways. Nonetheless, the teams varied in the extent to which they actually did this. For example, at Chelsea, team members reported that communication in the OR did not change, and as a result, according to Martha, "there is a painful process of finding out what didn't work, and saying 'we won't do that again.' We are reactive. The nurses have to run for stuff unexpectedly." In general, Chelsea personnel were not confident that the team had mastered the new technology; even the surgeon commented that after almost 50 cases at Chelsea "it doesn't seem to be getting that much better—we are a little slicker, but not as slick as I would like to be." As at other sites, Chelsea team members reported being amazed at the extent to which MICS imposed a need for a new style and amount of communication but were less confident that they were able to put this into practice. They displayed none of the enthusiasm for working more interdependently that we saw at Janus and Mountain. Instead, Martha expressed extreme frustration with the experience, telling us, "If I see an MICS case on the list [for tomorrow] I think, 'Oh! Do we *really* have to do this! Just get me a fresh blade so I can slash my wrists right now'."

At Janus, despite the lack of a thorough dry run, there was openness and camaraderie in the team. Adam, a perfusionist, reported that the team learned to communicate in a new way to accommodate MICS: "It is no longer surgeon outward; everyone has to talk to each other both ways. And I have to say to the anesthesiologist—don't do that until the balloon is up." Similarly, Sophia reported a change in routine as follows, "For [MICS] everyone is involved in the communication. ...I always take the initiative [to look at the vital pressures] because the surgeon is very busy with the anastomosis [stitching of vessels]." The team at Decorum, in contrast, appeared to be entrenched in old communication routines. When asked to describe how communication had changed for MICS cases, one nurse responded, "There's no difference... Only Dr. D and perfusion are talking." Neither the surgeons nor the rest of team spent time after the surgery discussing how the procedure went and what could be done differently. At Mountain, in addition to conducting a thorough dry run as a full team, the team gathered data to monitor both short- and long-term outcomes. Prior to each of the first 10 cases, the entire team met to discuss the proposed procedure for the case and met again after each of the first 20 cases to debrief. Subsequently, once team coordination was well established, the surgeons alone continued to meet to discuss each case.

Innovation. Teams varied in the degree to which they engaged in process innovation. Some teams, such as Janus and Mountain, made substantial changes in the procedure after getting comfortable with it, used the technology to carry out operations previously considered impossible, and changed patient eligibility criteria after reflecting on early MICS results. For example, at Janus, an OR nurse reported,

> [MISA] has been great at R&D. They take our suggestions and they come through with new changes. …[For instance, they] put markers on the balloon that makes it easier. Within nursing we've shared ideas and we keep making changes.

And a perfusionist at Mountain mentioned that the team "developed a special perfusion pack for [the company's] 3/8th inch line. We had [another medical equipment supplier] manufacture it Chelsea and Decorum teams did not report any process innovation.

Team learning behavior and adoption success. As these four cases suggest, team learning behavior is associated with adoption success. The full data set shows a similar pattern. To illustrate this association, Table 5 excerpts quotes relevant to team learning behavior from successful and unsuccessful adopters in the full sample. First, high adopters were more likely to conduct an inclusive and comprehensive dry run the night before their first case, by including every team member and discussing both technical and communication issues in this practice session. Thoroughness of team preparation was associated with implementation (rho=.63, p<.01). Second, successful adopters also appeared far more likely to substantially alter the way in which they communicated in the OR. As indicated in Table 5, there was little evidence of shifts in communication in low adopters. Third, process innovation (itself correlated with psychological safety, rho=48, p=.06) was weakly associated with adoption success (rho=.33, p=.10). Process innovation captures the ability of a team to utilize its own experience to reflect upon and make changes in its process—integral to the notion of team learning (Edmondson, 1999) and also can help the organization adapt the technology to be more acceptable in its own context (Leonard-Barton, 1988).

Proposition 3: Team learning behaviors facilitate successful adoption of technologies that disrupt organizational routines.

Table 5 about here

Effects of Boundary Spanning

Past research has shown that boundary spanning predicts performance for new product development, sales, and other teams (Ancona, 1990; Ancona and Caldwell, 1992). Similarly, new technology implementation should be more effective when OR teams actively communicate and coordinate with other clinical areas in the hospital that may be affected by the technology.

Although clinical areas in hospitals are often quite independent, in some sites, we found that the OR team established strong relationships with other groups, especially with cardiology and with ICU and floor nursing units, and that these sites were more likely to be successful adopters. A nurse from Mountain reported,

> We studied the manual then took it back to the [floor and ICU] nursing units and gave talks. We introduced the concept and what we were trying to do and how it would change the nursing role [in the units]. We looked for input from them.

In contrast, at Decorum, not only was communication within the OR sparse, communication across department boundaries was also limited. When we asked surgeons early in our visit for suggestions of cardiologists we could interview, they struggled to name one. An OR nurse reported,

> There is a territorial war in this institution on who controls echo. There was a huge compromise

> in that we finally got them [cardiology] to come in at 6:45, but it was a huge fight to get them to cooperate.

Similarly, no one in the OR team had communicated about MICS with the surgical intensive care unit (SICU), where post-operative patients were sent. As an OR nurse complained,

> I had to take a patient to the SICU and [MICS] had never been heard of, so I had to diagram it out for them. Should this be my responsibility? No. But it happened more than once, so the information didn't get to them.

In general, there was little cross-department coordination at Decorum ("there are no inter-area meetings here, not in this institution"). There were no formal meetings, and informal communication was limited. Jack told us that he learned more from interacting with MISA personnel than with others at Decorum.

At Janus, the OR team interacted extensively with clinical personnel across the boundaries of the operating room. Cardiac surgeons frequently conducted patient rounds in the ICU together with both cardiologists and anesthesiologists, a practice we saw at only two other hospitals. Further, cardiac surgery and cardiology engaged in frequent reciprocal decision making, through a weekly meeting between the two groups in addition to informal interaction. An administrator in cardiac surgery described it as a team approach: "Cardiology and Cardiac Surgery are a hand in hand relationship. Very much a team approach to a continuum of care. There is one goal—to treat the patient." The OR team also communicated with ICU personnel about MICS early on, enabling them to make changes to accommodate care of these patients. At Janus, boundary spanning primarily took place among physicians; OR nurses and ICU nurses, did not interact directly with each other. ICU nurses claimed that they did not discuss patients with other clinical areas, and one said, "we're not open [to that]."

As noted above, boundary spanning at Mountain was part of an explicit strategy. The surgeon explained his effort to coordinate with all clinical areas that might be affected by the new technology. After returning from training at MISA, he invited the cardiologists to a presentation in which he gave an overview of MICS and discussed its indications for use. He also organized a meeting with ICU and floor nursing staff, and invited input into designing new processes of care for patients treated with MICS. A result of these meetings was that ICU and floor nurses worked collaboratively with the OR team to modify the existing care plan for CABG patients to address specific needs of MICS patients. Finally, perhaps due to the OR team's ambassadorial activities (Ancona, 1990), cardiology and anesthesia had a good relationship, as reported by both groups, thereby avoiding conflict about the use of echo equipment in the OR. In contrast, in many of the hospitals studied, ownership of echo was tightly held by cardiology, creating many problems in using or getting assistance for echo in the OR for MICS. In the full sample, the interview measure of boundary spanning is significantly correlated with implementation outcome (rho=.66, $p<.01$), suggesting a fourth proposition.

Proposition 4: Boundary spanning (with other work groups affected by a new technology) facilitates successful adoption of the technology.

Effects of Team Stability

The relationship between team membership stability and learning or performance outcomes is a matter of some debate in the literature. On the one hand, keeping the same team members together may promote developing routines for coordinating interdependent work that are often tacit and thus difficult to transfer. On the other hand, over time, teams without member turnover may become slaves to routine and fail to respond to changing conditions. Experimental research has shown that keeping the same team members together promotes improved team performance on a new task (Moreland et al., 1998). Katz (1982) identified a changing relationship between membership stability and performance in product development teams, in which performance initially improves with greater stability, but after a point begins to worsen. We anticipated that team stability would promote both efficiency improvement and adoption success for MICS, as the process of learning the new procedure would be disrupted by changes in membership, leading to decrements in proficiency in the short term and in acceptance of the new technology in the medium term.

We did find considerable variance on team membership stability. Some surgeons explicitly planned to keep the teams stable for early MICS cases, to allow the team to become proficient; for example, at Mountain and Janus, team membership was kept completely stable for the first 30 and 15 cases, respectively. To explore the possibility that the proficiency surgeons hoped to gain by this would facilitate successful adoption—in part by allowing operations to be conducted in less time, thereby consuming less of the expensive resources of personnel and operating room time—we examined the correlation between adoption success and team stability and found that it was not significant (rho =.19, p = .47). In contrast, team stability and efficiency improvement were significantly correlated (rho=.50, p<.05). In sum, the data suggested that stable teams were able to improve procedure times more quickly than teams with greater turnover, but that this stability did not lead to adoption success. This leads to a fifth proposition:

Proposition 5: Team stability enables efficiency improvement in learning to use new technologies.

Effects of Organizational Factors

Past research has examined organizational characteristics such as absorptive capacity (Cohen and Levinthal, 1990) or resource allocation processes (Christensen and Bower, 1996) that foster innovation. Although the 16 sites studied here had profound organizational similarities, there were some differences in history of innovation, resources, and supportiveness of hospital administration for new technologies. Although we anticipated finding a positive association between these factors and adoption success, the data did not support this. For example, hospital administration at Janus, a successful adopter, virtually opposed the new technology, while Chelsea's administrators supported it to little avail. Mountain one of the two most successful adopters—lacked a history of innovation and had only moderate support from hospital administration. Administrators at Decorum—the least successful adopter—were extremely supportive of MICS. Resource constraints (a measure of organizational barriers to innovation) was only weakly negatively associated with adoption success (rho = -.20, p=.46).

DISCUSSION AND CONCLUSION

This study investigated factors affecting organizational adaptation to new technology in a particular industry context. Given how little was known about the phenomenon we studied—in general, for facilitating organizational adaptation to new technologies and, specifically, in the context of cardiac surgery—we explored a range of factors to allow patterns to emerge. The patterns that did emerge point to several factors that facilitate adoption success, even among hospitals similar in other ways.

First, surgeon coaching emerged as a critical variable—distinguishing successful adopters Janus and Mountain from unsuccessful adopters Chelsea and Decorum—as did team psychological safety, team learning behavior and team boundary spanning—characteristics of the teams implementing the technology. In contrast to previous research, organizational differences, such as history of innovation (high at academic hospitals Janus and Chelsea, lower at community hospitals Decorum and Mountain) and involvement of administration (high at Decorum and Chelsea, medium at Mountain, low at Janus) were not associated with outcomes. Thus, prestigious academic hospitals did not have an advantage over community hospitals in making MICS work. Just as two similar metropolitan teaching hospitals, Janus and Chelsea, had different outcomes (as did community hospitals Decorum and Mountain), the two most successful implementers in the full sample, University and Mountain, differed in hospital type.

Team Learning and New Technology Implementation

Despite the considerable structural homogeneity in the cardiac surgery context, there were substantial differences across organizations in how the new technology was implemented. To begin with, the degree to which adopting surgeons acted as coaching-oriented team leaders varied and appeared to matter greatly in promoting successful adoption. Team leader behavior encompassed two distinct activities: managerial (managing a project) and interpersonal (selecting and empowering a team). The lead surgeon at Mountain was unusually deliberate in exercising project management—imposing a high degree of structure on the learning process. He also was deliberate and articulate about empowering the team. In every site, informants volunteered descriptions of behavioral change (or lack thereof) in which the surgeon's behavior was causally implicated. These descriptions consistently suggested that surgeons somehow had to convey permission for others to speak up, if team members were to change their behavior in the ways the technology required. No non-surgeon team members reported strategies for working around or trying to influence surgeon behavior; unlike Barley’s (1986) Suburban technicians, these subordinate personnel appeared reliant on surgeons to take the first step toward forging new behaviors. In addition to encouraging speaking up, some surgeons also communicated a compelling rationale for MICS, helping to instill in the team a sense of meaning in the drudgery of enduring long procedures using initially cumbersome equipment. Thus, the anticipation of an MICS case on the following morning was met by Sophia at Janus with "gratitude" and by Martha at Chelsea with thoughts of "a fresh blade" to slash her wrists rather than going through the procedure again. The technology was, of course, identical at both hospitals. The social construction of the technology was vastly different (Barley, 1986). Building a sense of purpose and ownership in the team, for what the technology was accomplishing for patients, appeared to go a long way in fostering the effort and patience required for the new technology to succeed.

Given all of this, our first proposition related to the role of team leader behavior. A particularly compelling quantitative result, given the degree of independence of the two data sets, is the significant relationship between ratings of surgeon coaching and adoption success. On the one hand, the proposition that team leader behavior fosters project success is not surprising. On the other hand, deeply engrained institutional structures and cultural norms in cardiac surgery do not foster the proactive team coaching behavior that we observed in many of the successful hospitals. The teamwork members of the cardiac surgery community understand well is one in which every member’s job is important to the outcome, albeit some less important than others, while roles that dictate speaking patterns are sharply delineated. Thus, practicing a new kind of team interdependence went deeply against the norm. Consistent with Barley’s findings, our data do not suggest that surgeons at successful hospitals had to yield their expertise-based authority; instead, they simply adjusted to the absence of visual and tactile data by allowing themselves to be dependent upon others for verbal data. A possible psychological explanation for the differences we found in surgeon behavior across hospitals was that surgeons at unsuccessful hospitals could not separate reliance on others for data from loss of expertise-based authority.

Second, team leader coaching appeared to foster a variety of team learning behaviors. Thorough, inclusive, thoughtfully executed dry runs, in which teams could safely learn to work together before patients' lives were at stake, was one important team learning activity. Quantitative measures revealed a significant correlation between team preparation in a technically safe environment (as no patient is present) and adoption success. Ginnett (1990) and Gersick (1990) have discussed the importance of beginnings for teams, and these data support the notion that a good start provides a foundation for subsequent success.

A critical form of team learning in this context was speaking up about concerns and making observations that may turn out to be unimportant—in both cases risking censure by experienced surgeons whose expertise may lead them to view a particular comment as useless or disruptive. Thus, in this and other hierarchical contexts, psychological safety is likely to be particularly important for enabling behavioral change (Schein and Bennis, 1965; Schein, 1992). The data in this study did not allow us to disentangle constructs of speaking up (a form of team learning behavior) and team psychological safety (a shared perception describing how safe it is to speak up), since we lacked survey measures assessing people's perceptions of the interpersonal climate. Instead, we relied on interview data that included stories in which perceptions of the ease of speaking up were inextricably linked to stories of actually speaking up. Although this method did not allow the precision of a large sample study, it did allow us to gain insight into how people perceived their own situations when faced with the new technology. In addition, we devised two separate means of coding qualitative data (coding informants' responses during interviews and research assistants' identity-blind ratings of quotes) to promote reliability and to avoid eliciting only perfunctory responses—as all informants responded "of course" to a question in early site visits asking whether they would speak up if they saw a problem. To go beyond espoused views, first, we probed for and obtained many specific examples. Second, we devised a hypothetical situation in which the patient was in no immediate danger but a problematic trend was possible and asked informants what they would do. As illustrated above, this yielded strikingly varied responses, often grounded in specific behavioral examples, and strengthened the validity of our psychological safety measure, allowing us to glimpse what people actually did as well as how they perceived the interpersonal climate. Our second formal proposition was that psychological safety enabled adoption success, through team learning activities.

The successful adopters were far more likely to engage in extensive team learning behavior than the unsuccessful adopters: four of the seven successful adopters carried out thorough team preparation while only one of the unsuccessful adopters did this. As shown in Table 6, a set of group variables distinguished successful and unsuccessful adopters. Included in this set is boundary spanning. Several mechanisms may account for this. First, strong relationships with cardiology could help MICS succeed in two ways: by obtaining patients needed for early referrals for a novel surgical procedure and by supporting joint decision making about patient care, leading to better clinical decisions, allowing the technology to be well used. Second, communicating with the nursing units taking care of patients post-operatively could facilitate quick recovery and discharge, allowing benefits of the new technology to be realized, such as by early removal of the breathing tube used in surgery ("early extubation") in the ICU and early physical therapy. Without this coordination, MICS patients were often treated as conventional CABG patients—missing the opportunity for customized physical therapy and a shorter length of stay. Without the ability to show such benefits, it is likely that ongoing use of MICS would be jeopardized.

At the same time, as noted above and shown in Table 6, organizational variables such as innovation history and support of administration did not differ by outcome. Unlike in Barley's two hospitals, surgeon seniority and status here were unrelated to outcome. Similarly, some surgeons in the sample were well known for their skill, and succeeded as individuals in learning MICS, but their organizations were unsuccessful adopters, notably those at City, Chelsea, and Memorial. This is not to say that skill or fame was an impediment to adoption; the two surgeons at University, the most successful adopter, were equally well known and respected in the cardiac surgery community. Clearly, however, a surgeon's skill did not guarantee success. In sum, organization characteristics did not affect the capacity to adopt external innovations in this context, however, at the group level of analysis, the ability to absorb the new innovation varied enormously. Thus, an organization's absorptive capacity may not play a critical role in facilitating adaptation to an organizationally and interpersonally disruptive innovation. In these data, team learning—a kind of team absorptive capacity—was critical instead.

Table 6 about here

Learning to Be Efficient

We had anticipated finding that psychological safety would foster better communication, thereby promoting efficiency improvement in the OR, and were surprised to find no evidence of this in these data. Reflection on our results suggests an alternative theory, in which psychological safety is more important for encouraging behavior that stirs things up—creates change (process innovation), forges new relationships (boundary spanning), or speaking up (telling a surgeon what to do)—than for efficiency-oriented behaviors. Psychological safety facilitates expressing one's views and questioning others, rather than repetition and precision. The correlation between psychological safety and process innovation is consistent with this interpretation, while the proposition that team stability is critical to efficiency improvement has a high degree of face validity. Thus, team membership stability may foster collective learning (Moreland et al., 1998), but in this context it is associated with efficiency learning rather than with adoption success. This line of thinking raises the possibility of a trade-off between keeping the team small and stable to improve efficiency and expanding membership to engage more people in the project, allowing others in the organization to share ownership of it. If the MICS team is seen as exclusive, intergroup dynamics (Alderfer and Smith, 1982) may threaten the technology's acceptability of in the broader organization. This further suggests the possibility of a point at which the project—after gaining some momentum through a focused, stable team—may have to shift to be more inclusive if implementation is ultimately to succeed in the broader organization context.

The discussion thus far is captured in a model shown in Figure 1, in which team leader behavior gives rise to both psychological safety and team learning, which in turn facilitates successful adoption. At the same time, leaders also play an important role in creating team stability, which is proposed to promote efficiency improvement. The two outcomes—efficiency improvement and adoption success—were not correlated in this study, but future research is needed to investigate this relationship further.

Figure 1 about here

Limitations

Given the limitations of a case study approach, the propositions presented here are preliminary. Our sample was small for quantitative tests, and our statistical results are presented as preliminary support for new theoretical propositions. At the same time, our data have many strengths: they capture a variety of issues relatively systematically across 16 sites, with structured interview measures that benefited from being discussed in team meetings in which our multidisciplinary backgrounds prevented us from oversimplifying what we saw in the field. Independent coding of some of the qualitative data was used to increase confidence in our measures. However, further research is needed to develop the constructs and quantitative measures introduced in this paper. We did not obtain data on actual team conversations in the clinical context, but relied instead upon informants' stories, which provided sufficient information to allow us to speculate that the kind of subtle negotiation Barley (1986) documented in radiology departments might have preceded the striking differences we found. Lastly, given the specialized context of this study, concerns about generalizability of our propositions are discussed below.

Theoretical Implications

The results of this study have several implications for theory and future research. First, our model of team learning in the context of new technology implementation has the potential to make an important contribution to the research literature in healthcare management, as little attention has been paid to the effects of team dynamics on learning in medicine. Organizational learning is necessary for hospitals to continue to offer state-of-the-art care; however, there is necessarily an extremely low tolerance for failure in this learning process. Although recent attention in the national news media has raised awareness of the need for hospital cultures to shift to promote openness about mistakes to facilitate learning and improvement (e.g., Zuger, 1999; Pear, 1999), there has been little systematic research investigating the effects of organizational and managerial factors on these issues (cf., Edmondson, 1996). This study thus takes a first step in examining the role of team factors in managing change in healthcare.

A second implication concerns the problem of changing team routines. Researchers have discussed the nature of routine in work teams (Gersick and Hackman, 1990), but little is known about conditions in which teams accustomed to precise routines can adapt to new ways of working together. This study takes a first step in exploring this issue and suggests a critical role for team leader coaching and psychological safety in making this shift. Future research could fruitfully explore this issue more deeply.

A third theoretical implication of this study is suggested by considering how the model of team learning in Figure 1 fits into a broader context. Organizational researchers have argued both that organizational structures shape technological possibilities and that technologies give rise to structures that reflect implied task characteristics (Lawrence and Lorsch, 1967; Thompson, 1967). In both directions, the influence is depicted as widely applicable and largely unimpeded. More recent theory includes the notion that new technologies can chip away at existing structures, such that structure and technology exert a reciprocal, dynamic influence (Barley, 1986). The findings in this study raise a new possibility—that team learning can moderate the strong relationship between structure and technology. Well-led teams engaging in learning behaviors can loosen the strong hold that a structural context has on the acceptance of a new technology. New task characteristics thereby can be embraced in the face of resistant structures, if learning behavior occurs in an implementation team. Figure 2 depicts this proposition. Supporting this perspective, in this study, sites in which team learning was absent displayed the expected effect of structure on technology, such that the incongruence of MICS and existing social and organizational structures made implementation difficult. In contrast, in other sites, team learning—without altering the institutional context of cardiac surgery—did allow a new technology to take hold. A final theoretical proposition can thus be articulated:

Proposition 6: Team learning moderates the influence of institutional structure on technology acceptance.

Figure 2 about here

The findings of this study shed light on the challenges of new technology adoption in the face of well-defined institutional structures. They suggest that team learning behaviors can moderate the relationship between structure and technology. To what extent do the propositions discussed here apply outside of the cardiac surgical context? For new technologies that challenge behavioral norms and organizational routines, the models developed here may have considerable applicability. In particular, for technologies in which a multidisciplinary team is involved in implementation, facilitating team learning may be an important first step in enabling organizational adaptation. MICS is a technology for which mastery by one person—even the critical person—separately from a team appeared to be ineffective in ensuring organizational acceptability, as the experience at Chelsea illustrated vividly. For other technologies presenting similar challenges, such as enterprise resource planning (ERP) systems in manufacturing, or interactive software tools for team and project management, team learning is likely to be a factor in explaining differential adoption success.

In an industry context in which individual heroism and skill are assumed to be the critical determinants of important outcomes, this study produced evidence that empowering a team and managing a learning process matter greatly for an organization's ability to learn in response to external innovation. The data in this study did not tell a story of greater skill, superior organizational resources, or more past experience, as drivers of innovation. Instead, they suggested that face-to-face leadership and teamwork might allow some organizations to successfully adapt when confronted with new technology that threatens existing routines. These findings suggest the potential to impose an additional challenge on surgeons—and other team and project leaders—who already carry the weight of many burdens. Adding to their need to be skilled individual contributors, maintaining sophisticated technical expertise, they may also need to be skilled team leaders who can manage a project and create an environment in which team learning can occur. Similarly, engineers are asked to be leaders in technical firms, which increasingly rely upon teams to carry out strategically important projects, including adopting external innovations and developing new technologies internally. As teams become even more widely used to promote innovation in organizations, the need for the team leadership skills and team learning behaviors explored in this paper may become even more acute.

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APPENDIX: INTERVIEW QUESTIONS AND QUANTITATIVE MEASURES

Interview Questions

1. Can you tell us a little about how MICS got started at this hospital, and how it's going?
2. How were you selected to attend the training at MISA? What issues were considered in staffing the MICS team?
3. To what extent was the group that went to MISA working together as an intact team before training?
4. How many cases did the original team that attended training do together before new people started?
5. Did you do a dry run before the first case? Who was involved? What did you discuss?
6. Is there anything else that you have done to prepare for MICS cases?
7. When you first started doing the procedure, what were the eligibility criteria for selecting MICS patients? What are the criteria now?
8. When you started doing the MISA procedure, how many (surgeons, nurses, perfusionists, anesthesiologists) typically worked on a case? And now?
9. We would like to know if you have made any changes in the procedure, and if so, what, and what was the source and impetus for the change?
10. Have you used individual MICS devices for procedures other than CABG, MVR, or ASD?
11. Does the team meet to discuss MICS cases?
12. Do surgeons meet on a regular basis to discuss MICS cases?
13. Do other functions meet on a regular basis to discuss MICS cases?
14. During an MICS case, if you thought, for example, that the endoaortic balloon pressure might be [a number that is a little high], would you tell the surgeon?
15. Do you know what the surgeon's opinion is on why the department started using MICS technology?
16. When the surgeon makes decisions, does he do so independently or with input from others?
17. How much coaching does the surgeon do with members of the OR team?
18. How comfortable are you speaking up about a problem or mistake with him?
19. Is the adopting surgeon the chief of the department?
20. Can you tell us a little about the adopting surgeon’s management style?
21. Do you have planned meetings that include people from other clinical areas? How often? Who attends?
22. When you go on rounds, who typically accompanies you?
23. Can you describe the process by which patients are referred from cardiology to cardiac surgery?
24. Describe the interaction between cardiac surgery and cardiology.
25. Describe your interaction with the ICU…with the floor…
26. Who has primary responsibility over patients’ post-ICU care? Is there a Care Path for MICS patients?
27. Have you ever converted a patient intended for MICS to a median sternotomy? What was the reason?
28. For how many days per year do you attend conferences or professional continuing education programs? What is the nature of this hospital's support for education and development?
29. How many colleagues at other hospitals do you speak with on a regular basis?
30. Why did the hospital start doing MICS procedures?

31. What was the role of the hospital administration in the decision to start doing MICS procedures?
32. Since then, has the administration been active in evaluating or promoting the MICS program? In what way?
33. Who is responsible for the MICS program?
34. What are the most important factors limiting the number of MICS cases thus far?
35. Does the number of cases surgeons do influence their compensation?
36. Five to ten years from now, what percentage of cardiac surgeries do you think will be minimally-invasive, not just MICS?
37. Over the past 10 years, how many other major cardiac surgery innovations has this institution adopted or clinically evaluated?
38. Does this hospital do heart transplants?
39. Can everyone see the monitors?
40. Does the surgeon wear a head camera?
41. What is different about working in this hospital, compared to other hospitals in which you've worked?

Quantitative Measures

Organizational-level variables

Size. The number of cardiac surgical operations conducted per year.

Resource constraints. From responses to an interview question about factors limiting the number of MICS cases performed at a site, we identified three barriers: (1) capacity constraints (operating room and/or surgeon time—the long MICS procedures consume more of these resources than conventional surgery), (2) high cost of the MISA product, and (3) lack of referrals for MICS. We measured resource constraints as the total number of barriers identified by informants at each site.

Extent of data use. Hospitals varied in the way data on cardiac surgery procedures were used and who used them. In some hospitals, data were used for research and academic publishing only; in others data were used for a range of applications including research, benchmarking and quality improvement. An interview variable ranging from zero to six counted the number of different uses of data at each site. Another variable ranging from zero to nine counted the number of administrative and clinical groups actually using the data. The sum of these two variables (correlated at .50) created a measure the *extent of data use* at each site, which ranged from 0 to 15.

History of innovation: An interview question asked about other cardiac surgery innovations adopted or clinically evaluated at the hospital, and responses were coded as (4) extensive (when all recent innovations in cardiac surgery had been tried at that hospital including heart transplants, (3) high (when all or almost all recent innovations were tried, (2) moderate (when 1 or 2 had been tried), (1) none (when no other innovations had been tried).

Support of administration: Interviews assessed the role of hospital administration in MICS adoption as (4) initiated plan and promoted it actively, (3) supported MICS adoption, although it was initiated by surgeons, or (2) neutral or not involved, (1) opposed MICS.

Group-level variables

Team leader coaching. Two research assistants rated 613 quotes previously identified as related to team leader behavior on a three point scale from high (creates an open environment, leads discussion, creates trust, advocates teamwork) to low (doesn't coach, doesn't listen to others, doesn't trust the team, disregards importance of teamwork). One of the authors conducted a one-hour training session for the raters on how to assess leadership quotes, using a written guideline specifying typical markers of each point in the scale. Raters had the option of using a 9 to indicate that a quote was not relevant to coaching behavior; 262 of the 613 quotes received a scaled rating and the others quotes were related to leader behavior but not to coaching. Quotes were not identified by hospital and were scrambled. Thus, one-way ANOVA was used to show that ratings of quotes were similar within and varied significantly between hospitals ($F_{(16,262)}$=7.15, p<.001), supporting aggregation to a group-level measure. The correlation between the two raters' scores at the quote level of analysis was .80 (n=613) and at the group level was .94 (n=16); the two raters' scores were averaged to produce one measure of coaching behavior.

Team composition planning. Responses to interview questions about how MICS teams were selected were coded into one of four categories by the interviewers: (4) all team members were hand picked by surgeons for specific competencies such as the ability to train others or the ability to work well in a team, to (3) deliberate selection of team members within each role area to (2) selection of some but not all team members, to (1) virtually random assignment of nurses, perfusionists, anesthesiologists and even surgeons to attend the training program.

Team stability. Two variables in the structured interview data set assessed team stability. One is the number of operations that informants reported being conducted by the original team and the other was the espoused strategy for team stability, coded into one of four categories by the interviewers: (4) deliberately kept stable for at least 10-15 cases, (3) stable with staged inclusion during early cases, (2) immediate inclusion of new members, and (1) immediate substitution of new members. These two variables (r=.65, p<.01) were standardized and averaged to produce a measure of *team stability.*

Psychological safety. To obtain a measure of psychological safety, notes from informants' responses to several questions about the team, including what they would do if the balloon pressure was marginally low, were coded as follows: the atmosphere and interaction in this team is characterized by (3) open reciprocal communication (very free and effortless), (2) respectful but guarded communication (picking the right moment to speak, pronounced awareness of status differences) and (1) communication that is quite limited, with some members extremely hesitant to speak up. Additionally, two research assistants rated 168 quotes previously coded as relevant to *ease of speaking up* on a three-point scale from high (easy to speak up about anything on one's mind) to low (people appear to be very uncomfortable speaking up and only do it under extreme duress). One of the authors conducted a one-hour training session for the raters on how to assess quotes, using a written guideline specifying typical markers of each point in the scale. Raters used a 9 to indicate that a quote was not relevant to the construct only once. One-way ANOVA showed significant differences in ratings across hospitals ($F_{(16,168)}$=7.66, p<.001), but no difference across professions within hospitals ($F_{(4,168)}$= .29, p=75). The correlation between the two raters' scores at the quote level of analysis was .75 (n=168) and at the group level was .94 (N=16); the two raters' scores were averaged to produce one measure, then aggregated to produce a group-level measure—which was significantly correlated with psychological safety (r=.80, N=16, p<.001).

Boundary spanning. Responses to interview questions (21-26) asking about inter-area relationships were coded to create three dichotomous (yes=1/no=0) variables assessing the existence of reciprocal communication between adjacent groups in the care process for cardiac surgery patients (OR team/cardiology, OR team/ICU and OR team/floor). The sum of these three variables provided a measure of *boundary spanning*. The average correlation among these three variables was 0.47 and the composite variable ranged from 0 to 3.

Team preparation. Responses to interview questions (5 and 6) about team preparation were coded into two variables. The first assessed who participated in a dry run: ranging from (1) no one, to (2) isolated disciplines, (3) pairs of disciplines, (4) most of the team (5) the entire multi-disciplinary team—or all four disciplines. The second assessed session content: from (1) no content (when there was no session), to (2) technical review of the equipment and procedure, and (3) technical review together with thorough discussion of communication issues such as how the team would talk and interact. These two variables were correlated (.93) and added together to make a composite variable measuring *team preparation*, ranging from 2 (1+1) to 8 (3+5).

Process innovation. Responses to interview questions (9 and 10) created a composite variable to assess the *process innovation* as follows: (1) deliberately changing patient eligibility criteria as a result of reflection on past surgical results (coded as 1 or 0), (2) introducing specific improvements or innovations in the procedure that constituted substantive changes to improve MICS (also coded as 1/0), and (3) using MISA devices for procedures previously considered impossible (1/0). The sum of these three correlated variables (average r = .46) provided a measure of process innovation, which ranged from 0 to 3.

Team stability. Responses to interview questions (2, 3, 4) addressing team stability were coded as follows. First, the raw number of operations informants reported being conducted by the original team was noted and averaged across informants within a site. Second, the espoused strategy for team stability was coded into one of four categories by interviewers: (4) deliberately kept the team stable for at least 10-15 cases, (3) kept the team stable with staged inclusion during early cases, (2) allowed immediate inclusion of new members, and (1) allowed immediate substitution of new members. These two variables ($r=.65$, $p<.01$) were standardized and averaged to produce a measure of *team stability*.

Learning outcomes

Efficiency improvement: Procedure time reduction is measured by the individual hospital coefficient for the interaction term in the following model:

$$\ln(\text{Procedure Time}_i) = \alpha_0 + \beta_0\text{CABG}_i + \beta_1\text{Grafts}_i + \beta_2\text{ASD}_i + \beta_6\ln(\text{Cumulative Volume}_{ij}) + \beta_4\text{MultiProcedure} + \beta_5\text{Higgins}_i + \beta_{7j}\text{Hospital}_j + \beta_{8j}\text{Hospital}_j * \ln(\text{Cumulative Volume}_{ij}) + e_{ij}.$$

Procedure Time_i is the number of minutes required to perform the procedure on the ith patient; CABG is dummy variable for coronary artery bypass; Grafts is how many veins or arteries were bypassed on the ith patient; ASD is a dummy variable for Atrial Septal Defect repair, Multi-Procedure is a dummy variable coding for whether multiple types of repairs were performed; Higgins is a control variable based on the Higgins Score to adjust for the health status of the patient; Cumulative Volume_{ij} is the number of prior MICS cases performed at hospital j when patient i had his/her operation, and Hospital_{ji} is a vector of j dummy variables indicating at which hospital patient i had the operation. The interaction term provides the specific learning curve coefficient for each site.

Adoption success: The sum of the ranks of three variables drawn from hospital archival data: (1) the number of MICS cases conducted in the first six months at each site, (2) the percent of cardiac operations conducted using MICS in the same period, and (3) whether a site was increasing, decreasing, or steady in its use of MICS.

Table 1

Research Sites

Hospital	Organizational Size Index (*Annual Cardiac Bypass Operations)*	Hospital Type	Region	Status of Adopting Surgeon	Number of Interviews Conducted
Chelsea Hospital	378	Academic	Mid-Atlantic	Dept. head	9
City Hospital	800	Academic	Northeast	Dept. head	7
Decorum Hospital	1330	Community	Mid-Atlantic	Dept. head	12
Eastern Medical Center	1600	Academic	Northeast	Senior surgeon	11
Janus Medical Center	1100	Academic	Midwest	Dept. head	10
Memorial Hospital	1444	Academic	Northeast	Senior surgeon	7
Mountain Medical Center	1200	Community	Southeast	Junior surgeon	11
Regional Heart Center	3678	Academic	Midwest	Junior surgeon	8
Saints Hospital	1000	Community	Southeast	Senior surgeon	7
Southern Medical Center	1900	Academic	Southeast	Senior surgeon	10
St. John’s Hospital	1300	Community	Southwest	Senior surgeon	8
State University Hospital	600	Academic	West	Senior surgeon	11
Suburban Hospital	2507	Community	Mid-Atlantic	Senior surgeon	11
University Hospital	1200	Academic	Mid-Atlantic	Dept. head	9
Urban Hospital	560	Community	Midwest	Senior surgeon	10
Western Hospital	1636	Community	Midwest	Senior surgeon	7

Table 2

Construct Definitions, Internal Consistency Reliability and Discriminant Validity of Composite Variables[a]

Variable name	Description	Number of questions	Cronbach's alpha	Average within-construct correlation	Average between-construct correlation
Extent of data use	Collection and use of data for organizational improvement and academic research	2	.64	.50	.05
Team stability	Degree to which membership of the team implementing MICS is consistent across successive procedures using the technology.	2	.79	.65	.03
Boundary spanning	Degree to which the OR team communicates and coordinates with other clinical areas—cardiology, the ICU and the floor.	3	.71	.47	.26
Team preparation	The degree to which the team engaged in an inclusive (how much of team was present) and comprehensive (degree to which content included both technical and communication issues) dry run in advance of the first case with a real patient.	2	.85	.93	.31
Process innovation	The degree to which the OR team made substantial changes in the operative procedure using the new technology based on reflection on past results.	3	.72	.46	.17

[a]. Chronbach's Alpha is used to establish internal consistency reliability, and showing that average within-construct correlation for each composite variable is substantially larger than average between-construct correlation demonstrates discriminant validity.

Table 3:
Major and Minor Categories for Coding Qualitative Data

Major Category	Minor Categories
Boundary Spanning	Cardiology relationship Care paths Echo (ownership of echo technology) Interdisciplinary communication ICU/Floor relationships Referral patterns
OR Team	Ease of speaking up Culture of cardiac surgery group Communication behaviors during MICS Dry run Debrief meetings for MICS Planning for MICS communication Selection of team members Team stability
Hospital Culture and History	Responses to adverse events This hospital is different because…(unique traits) Satisfaction with hospital/job Hospital support for training/continuing education Role of hospital administration Formal processes for technology adoption/assessment History of/attitude about technology adoption
Leadership	Attitude/Behavior of Adopting Surgeon Attitude/Behavior of Department Head Deliberate choice of leader Status of adopting surgeon
Data Use	Data collection for MICS Data collection/use (in general) Reviewing reports, aggregate data
Views of MICS and MISA	Attitude toward MICS project MISA People/Company MICS Technology Future of Minimally Invasive Techniques Outcomes/Benefits of MICS Reasons for adoption Technical aspects of MICS

Table 4: Comparison of Core Constructs across Four Cases

	Chelsea Hospital	*Janus Medical Center*	*Decorum Hospital*	*Mountain Medical Center*
Hospital Type	Academic	Academic	Community	Community
History of Innovation	Extensive	Extensive	Moderate	Limited
Support of Hospital Administration	Supported surgeon's request with commitment of resources	No support; opposed "time off" for staff to go to training,	Supported and promoted use of new technology in hospital	Supported surgeon's request with commitment of resources
Team Leader's Position	Head of Department	Head of Department	Head of Department	Junior Surgeon
• Leader Coaching Behavior	Surgeon didn't practice with the team because, "the technical aspects [of MICS] are not much," so "it was not a matter of training myself, it was a matter of training the team."	Surgeon carefully communicated rationale and benefits of technology to team. "He takes the lead, he talks everyone through it. He says things like, 'can you see it?' and so on…" (nurse, describing surgeon)	"He's very much the commander of the ship" (anesthesiologist) "There was a case with a [complication]. I told him [about it] and I was blown off." (nurse, describing surgeon)	"The surgeon empowered the team. That's why I'm so excited about MICS. … it is about what a group of people can do…"(perfusionist) "The surgeon said, 'hey, you guys have got to make this thing work. That's a great motivator." (perf)
• Team Psychological Safety	"if you observe something that might be a problem you are obligated to speak up, but you choose your time…" (nurse)	"I am very comfortable speaking up… you have to talk …there is no chance for recovery…" (nurse 2)	If I sensed a potential problem, "I'd tell the adjunct, or I might whisper to the anesthesiologist … [people] are afraid to speak out…"	"there's a free and open environment with input from everybody" (nurse)
• Team Preparation	Dry run with no surgeons	Dry run with no surgeons	Just read manual	Full team dry run, with thorough discussion of how to communicate during MICS
• Boundary Spanning	Asked if cardiologists have a positive view of MICS, surgeon replied, "I don't know. …there's a joint meeting once a year between cardiology and surgery."	"Cardiology and cardiac surgery are a hand in hand relationship. Very much a team approach to a continuum of care…" (CS Administrator)	"there is a territorial war in this institution as to who controls echo" "There are no inter-area meetings here. Not in this institution." (nurse)	Surgeon organized a series of meetings with the OR team and other clinical areas (cardiology, ICU nursing, floor nursing).
Debriefing	None	Unstructured debriefing,in OR and in impromptu meetings	None	Full-team sessions after first 15 cases; surgeon debrief sessions for next 20 cases
Team Stability	Team composition kept stable for 12 cases, to streamline procedure.	Team composition kept stable for 30 cases; surgical procedure kept stable for 15 cases.	Team composition was stable, with the exception of 2 members who left the hospital	Team composition kept stable for 15 cases; surgical procedure kept stable for 30 cases.
Implementation Index Rank	10	3	16	2
Efficiency Improvement Rank	7	10	8	1

Table 5: Sample Quotations on Team Learning Behaviors and Team Boundary Spanning for Entire Sample

	Seven Most Successful Adopters	Seven Least Successful Adopters
Team Preparation	[To prepare for our first MICS case], we met informally. We discussed all of the possible bad outcomes and how we would deal with it. Then, we did a dry run and went through the scenarios that Dr. B and I had conjured up. We did a literature search and gleaned all the worst case scenarios and then took this to the dry run. (Surgeon, Western Hospital)	[To prepare for our first MICS case, we] kind of more or less looked at the room. (Physician's Assistant, Decorum Hospital)
	The night before [our first MICS case] we did everything. …We had a couple of talks in advance and the night before we walked through the process step by step. Took two and half or three hours. We communicated with each other as if it were happening, i.e., the balloon is going in, etc. [Then, Dr B] gave us a talk about what Heartport is about. The kind of communication he wanted in the OR, what results he expected, and told us to immediately let him know if anything is out of place. (Perfusionist, Suburban Hospital)	When asked if he did anything to prepare: "Not really. Extensive background reading of course. I felt well prepared. A little trepidation but ready to go." (Surgeon, Decorum Hospital) We had to adapt the setup and change the displays. Everyone was there but the nurses. (Anesthesiologist, City Hospital)
Change in Communication and Coordination	If an unusual case is coming up, I ask surgeons about it, look at the literature, and talk with the surgeons beforehand. The surgeons have become very open to me bugging them on that level. It used to be viewed skeptically, but they have grown to expect that interaction from me. This is true of other perfusionists, too. They learned the process of talking with the surgeons…(Perfusionist, Mountain Medical Center)	[Since starting to do MICS cases], there's more yelling. There's a greater need for communication between perfusion and anesthesiology. [But, the surgeon does not communicate] all that much. (Nurse, Chelsea Hospital) If you saw something that was a problem, you were obligated to communicate, but you'd choose your time. (Nurse manager, Chelsea Hospital)
	The MICS procedure is a paradigm shift in how we do surgery. It is not just techniques, but the entire operating room dynamics. The whole model of surgeons barking orders down from on high is gone. There is a whole new wave of interaction. There are multiple new tasks involved by a number of specialties. (Surgeon, Mountain Medical Center)	I wouldn't speak up if I weren't confident that a mistake would lead to an adverse outcome. I'm not comfortable hypothesizing. (Anesthesiologist, City Hospital)
	We all have to share the knowledge. For example, in the last case, we needed to reinsert a guidewire and I grabbed the wrong wire and I didn't recognize it at first. And my circulating nurse said, "Sue, you grabbed the wrong wire." This shows how much the different roles don't matter. We all have to know about everything. You have to work as a team. (OR Nurse, Urban Hospital)	Now that I've been working with them, even if I'm wrong, I might get yelled at, but I would [speak up]. Sometimes they appreciate it. They have a lot going on. (OR Nurse, Regional Heart Center) There was more communication when we first started because of the unfamiliarity. (Anesthesiologist, Regional Heart Center)
	The team [involves] everybody sharing. If you are wrong, you are told. There are no sacred cows. If somebody needs to be told something, then they are told. Surgeon or orderly. (Perfusionist, Western Hosp)	We focus more on the clamp. They watch to see if it is slipping. Monitoring the clamp is a big issue. Otherwise it is not that different from conventional cases. We each focus on a job. We

	[The communication pattern] used to be table to perfusionist, table to nurse, table to anesthesiologist. Now it is perfusion to anesthesia, nurse to surgery, anesthesia to surgery—all relationships. Everyone communicates. There is a lot of information. There are two or three sources of information--the monitors, the TEE, the fluoro –and we all discuss it. (Perfusion, Urban Hospital) I noticed from [visiting other hospitals] that centers that are successful with the MICS procedure are the ones that communicate well. At Southern, it's never been a problem. (Anesthesiologist, Southern Medical Center)	don't need to communicate with each other much. We are seasoned professionals. (Perfusionist, Memorial Hospital) [Any discussion of MICS cases] is impromptu. Three perfusionists might meet informally fairly often, but there are no formal meetings. (Perfusionist, Regional Heart Center) There was a case with a [complication]. I told them the pulses were missing and I was blown off. I told the fellow. If you want to, you go to the fellow or the SICU attending. (ICU Nurse, Decorum Hospital) The surgeon doesn't communicate much about what he's doing, but lately he has been wearing a camera. And that made a difference, at least for him. (Anesthesiologist, Regional Heart Center)
Process Innovation	[MICS] allowed us to do some cases that would have been difficult otherwise. (Cardiologist, Southern Medical Center) The company has been great at R&D. They take our suggestions and they come through with new changes. . . .[For instance, the company] put markers on the balloon. That makes it easier. Within nursing we've shared ideas and we keep making changes." (OR Nurse, Janus University Hospital) We developed a special perfusion pack for [the company's] 3/8th inch line. We had Butler manufacture it for us. (Perfusionist, Mountain Medical Center)	We tried to do it our own way. We used our own perfusion apparatus for perfusion activity. But after six cases we did it their way. (Perfusionist, City Hospital) The problem with MICS is that it is too rigid and lacks adaptability. (Perfusionist, Regional Heart Center) We discussed changes but we didn't make any. It is safer just to stick with it. (Perfusionist, Regional Heart Center)
Boundary Spanning	We run a single service with cardiology and cardiac surgery rounding on post-op patients together. It helps me personally, because I make life-threatening decisions and this way I see the consequences of my decisions. Lots of cardiologists [in other hospitals] don't see patients post-operatively. (Cardiologist, Southern Medical Center). It has always been cross disciplinary here. (Data coordinator, Urban)	We used to have them [meetings with people from other clinical areas] but the economics of the hospital mandated eliminating meetings.. . We meet by discipline. (Anesthesiologist, Memorial Hospital) This is a very, very independent hospital. We are service oriented. Each team functions within itself. (OR Nurse, Memorial)

Table 6: Comparison of Successful and Unsuccessful Adopters on Group and Organization Factors

Factor Level	*Construct*	*Successful Adopters*							
		University Medical Center	Mountain Medical Center	Western Hospital	Urban Hospital	Janus Medical Center	Southern Medical Center	Suburban Hospital	**Number of Highs**
Group	Team Leader Coaching[a]	H	M	H	H	M	H	H	**5**
	Psychological Safety[b]	H	M	H	H	H	H	H	**6**
	Team Preparation[c]	H	H	H	H	M	L	M	**4**
	Process Innnovation[b]	H	H	M	L	M	H	M	**3**
	Boundary Spanning[d]	H	H	H	H	H	H	M	**6**
	Team Stabilty (# Operations[e])	L	H	M	H	H	L	L	**3**
Organization	Low Resource Constraints[d]	H	H	H	H	H	M	M	**5**
	Support of Hospital Administration[b]	M	M	M	L	M	H	M	**1**
	Innovation History[b]	M	M	M	M	H	H	M	**2**

Factor Level	*Construct*	*Unsuccessful Adopters*							
		Chelsea Hospital	State University Hospital	City Hospital	Eastern Hospital	Memorial Hospital	Regional Heart Center	Decorum Hospital	**Number of Highs**
Group	Team Leader Coaching[a]	M	M	L	H	M	M	L	**1**
	Psychological Safety[b]	M	M	L	H	M	M	L	**1**
	Team Preparation[c]	L	L	L	H	L	L	L	**1**
	Process Innnovation[b]	M	M	L	H	M	M	L	**1**
	Boundary Spanning[d]	M	M	L	H	L	M	L	**1**
	Team Stabilty (# Operations[e])	M	M	L	L	M	L	H	**1**
Organization	Low Resource Constraints[d]	M	M	H	H	L	H	H	**4**
	Support of Hospital Administration[b]	L	M	M	L	L	M	H	**1**
	Innovation History[b]	M	H	M	H	H	H	M	**5**

[a] $H \geq 2.5$ M=1.5-2.5 $L \leq 1.5$
[b] H=3 M=2 L=1
[c] H=8 M=4-5 L=1-2
[d] H=4 M=2-3 L=1
[e] H=15-33 M=10-12 L=0-5

Figure 1: A Model of Team Learning in New Technology Implementation

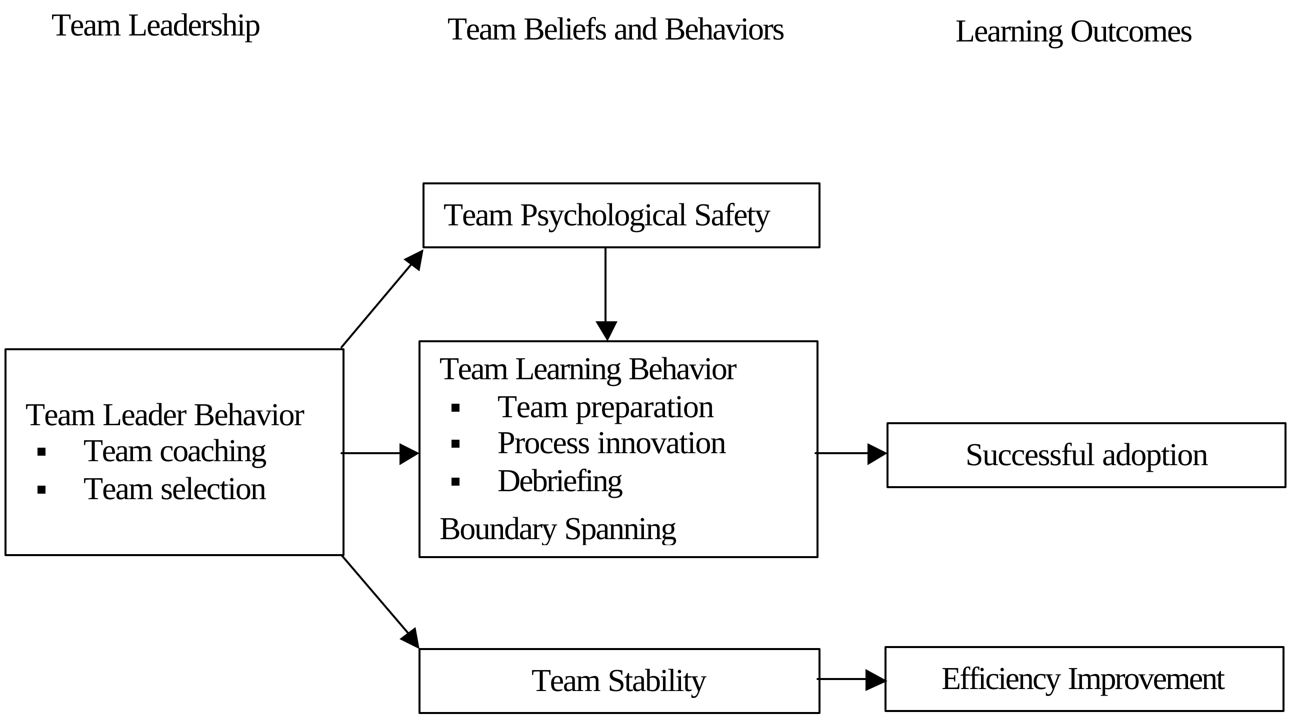

Figure 2: Team learning as a moderator of the relationship between structure and technology