

Perfect Match

TEAM APPLIES
SIX SIGMA TO
REDUCE TIME
IT TAKES TO
QUALIFY PATIENTS
FOR KIDNEY
TRANSPLANTS

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In January 2008, the University of Toledo Medical Center (UTMC) in northwest Ohio collaborated with the University of Toledo's Industrial Engineering Department to analyze and improve the preoperational processes for patients undergoing kidney transplants. Six Sigma was applied to the project, and the following goals were established:

- Optimize cycle times.
- Enhance customer satisfaction.
- Improve efficiencies.
- Reduce costs.
- Streamline administrative processes.
- Eliminate errors.
- Improve protocol execution and effectiveness.

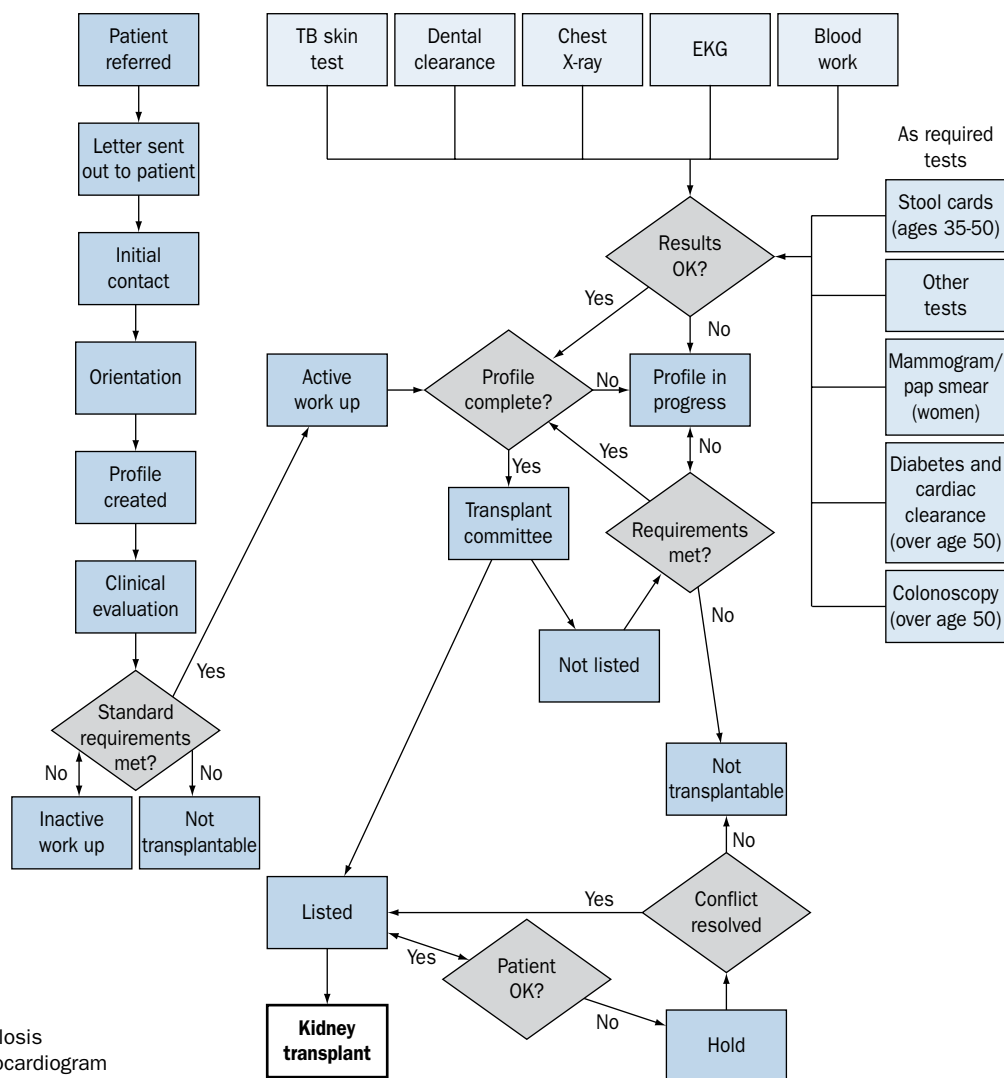
The project's primary metric was the number of days required from the date a patient was referred to UTMC for a kidney transplant to the date the hospital staff declared the patient a suitable transplant candidate. The research was needed and the project selected because of an increase in the number of patients awaiting transplants and the number of transplants performed per year because of the increased service area for UTMC. Because of a waiting list of nearly 500 patients, it was determined a reduced cycle time would save lives.

Background and terminology

For more than 30 years, UTMC has performed adult and pediatric kidney transplants as one of the treatment options for end-stage renal disease. Since UTMC's first kidney transplant operation in 1972, more than 1,500 kidney transplant operations have been performed there, with an average patient survival rate of 98% and a graft survival rate of 94%. The program relies on advanced surgical techniques—including laparoscopic kidney donation, improved anti-rejection medications and high-quality patient care—to make it one of the most successful programs in the country.

There are a number of steps patients must complete before receiving a kidney transplant. Generally, the patient must be referred to a medical center and complete required labs and tests to determine if he or she is suitable. The labs and tests are usually similar among all transplant centers and among patients. The labs include tuberculosis (TB) tests, dental clearance, a colonoscopy, chest X-rays, electrocardiography tests, stool samples, blood work, mammograms, pap smears and diabetes tests. Once the patient fulfills the requirements, a committee reviews the results and determines whether the patient is a good candidate. The patient is then allowed to receive a kidney; this is called being "listed," or placed on the waiting list.

Figure 1. **Process flow map**



Often, the time required to complete these health screenings is up to nine months. In addition, another two years may pass after the patient is listed before a kidney transplant is performed.

It is difficult to reduce the waiting period between being listed and receiving a kidney because it's dependent on the number of kidneys available and the number of kidneys needed. Improvements can be made, however, for reducing the time required for a patient to become listed.

The UTM Six Sigma project team was composed of two surgeons, three transplant coordinators/registered nurses, a psychologist, a financial advisor and two industrial engineers. The team adapted a plan from *Improving Healthcare Quality and Cost With Six Sigma*¹ and

Partnering With Your Transplant Team, The Patient's Guide to Transplantation.²

The team deployed the define, measure, analyze, improve and control (DMAIC) approach for this Six Sigma project. The following sections highlight each step and the statistical tools applied to conduct the analyses.

Define

The specific goal was to reduce the cycle time from 227 days to 180 days or less. The primary metric for this project was the average total preoperational process time—measured in days and calculated from patient records—for patients undergoing kidney transplants.

From the preceding two years, the process was baselined at an average of 227 days. To ensure the process was patient-centered, the team applied concepts from *What Every Patient Needs to Know*.³ These concepts revolved around patient involvement and communication with the care team.

Measure

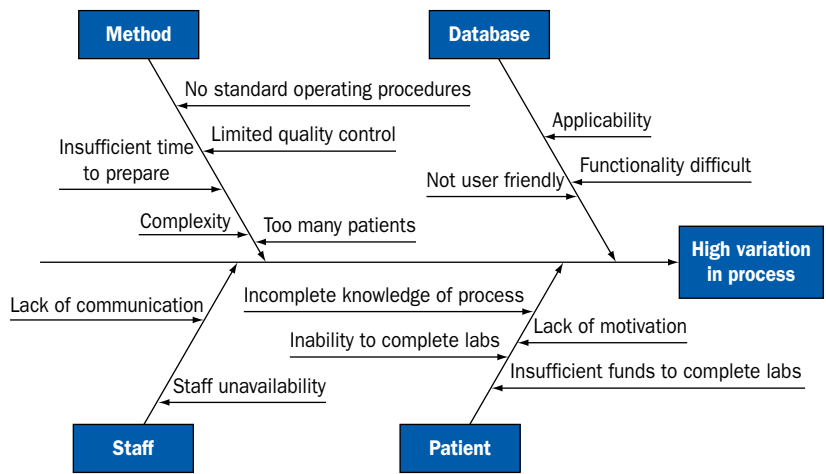
In this phase, the team identified key metrics, developed and executed the data collection process, baselined the performance and variation of the current system, and calculated the initial sigma level. The team also developed a suppliers, inputs, process, outputs and customers (SIPOC) diagram (Table 1) and process map (Figure 1, p. 11) in this phase.

The output variable analyzed for this process was the time required from a patient’s referral to UTMC to the time the patient was evaluated by medical staff, cleared as a suitable candidate and placed on the waiting list. The Six Sigma team conducted a brainstorming session using a fishbone diagram (Figure 2) to identify causes of variation in the system.

The input variables (potential vital Xs) included:

- Lack of real-time patient data.

Figure 2. **Fishbone diagram**



- Doctors’ and nurses’ different data-collection procedures.
- Scheduling conflicts between staff and patients.
- Lack of communication among staff.
- Staff’s availability.
- Patients’ delays and cancellations.
- Lack of funds from the patient.

Data from the previous two years were collected for this project using patient record review, database review and real-time data collection from current

Table 1. **SIPOC diagram**

Suppliers	Inputs	Processes	Outputs	Customers
Medical supply companies	Patients	See Figure 1’s process flow diagram	Implanted kidney	Patients seeking transplants
Insurance companies	Donated organs		Payment	Family and friends of patients
	Medical staff			Insurance companies
				Medicare

Table 2. **Process baseline measurement**

	Time between referred and letter	Time between letter and orientation	Time between orientation and clinical evaluation	Time between clinical evaluation and transplant committee	Time between transplant committee and listed status	Total process time
Average days	5	40	68	102	13	227
Standard deviation (days)	6	22	27	82	15	45.6
Average months	0.16	1.34	2.27	3.39	0.42	7.58
Standard deviation (months)	0.19	0.72	0.89	2.74	0.50	1.52
Number of samples	91	81	97	136	104	509

Table 3. **Confidence interval**

95% confidence (days)	Time between referred and letter	Time between letter and orientation	Time between orientation and clinical evaluation	Time between clinical evaluation and transplant committee	Time between transplant committee and listed	Total process time
Z-value	1.96	1.96	1.96	1.96	1.96	1.96
Interval	1.23	4.79	5.37	13.78	2.88	3.96
Upper bound	6	45	73	116	16	231
Average	5	40	68	102	13	227
Lower bound	4	35	63	88	10	223

patients. The data were collected by the cross-functional team using standardized forms.

The team established meaningful Six Sigma metrics based on this data and the project goal. These metrics included the process cycle time, sigma quality level, process capability, defects per million opportunities and yield.

The goal of six months (180 days) for the completion of the evaluation process for each patient was established based on the minimum time required for the various tests, the patient’s own delays and the critical nature of transplants to save lives. The current mean process cycle time was 227 days, with a standard deviation of more than 45 days.

Based on a sampling of 509 patients, 433 patients (85.1%) required more than 180 days for the evaluation process. This translated into less than 15% of all patient evaluations achieving the 180-day goal. The 14.9% acceptance rate translated into 851,000 defects per million opportunities, or a 0.46 sigma level, for the current process.

Analyze

The team applied many Six Sigma tools to understand process capability and identify the vital Xs, or the root causes, of process delays requiring more than 180 days. The tools and data-analysis methods included:

- Process capability analysis.
- Confidence and prediction intervals.
- Pareto analysis.
- Five whys analysis.
- Root cause analysis.
- Regression analysis.
- Failure mode effects analysis (FMEA).
- Work sampling.
- Value stream mapping.

Before identifying and analyzing root causes, the

team established a baseline for the current process performance and performed a process capability analysis. Table 2 summarizes the findings of the review of more than 500 patient records during the past five years.

Table 2 also shows the high process average and standard deviation between the time the patient receives a letter of acceptance to the wait list and the patient’s orientation. This is because orientation is offered once a month. Clinical evaluations are offered two days each week and are scheduled months ahead of time, contributing to the high average and standard deviation for the time between orientation and clinical evaluation.

The time between the clinical evaluation and the transplant committee’s review shows a high average and standard deviation because the patient has to complete all of the required labs and tests. The number and type of tests required are based on the individual patient.

The average and standard deviation for the time between the transplant committee and being listed was higher than expected because of the coordinators’ workloads. From a process capability standpoint, the process is not capable of performing within specifications in the current state as calculated with a C_{pk} value of -0.34. The negative C_{pk} value strongly suggests the

Figure 3. **Processing time histogram**

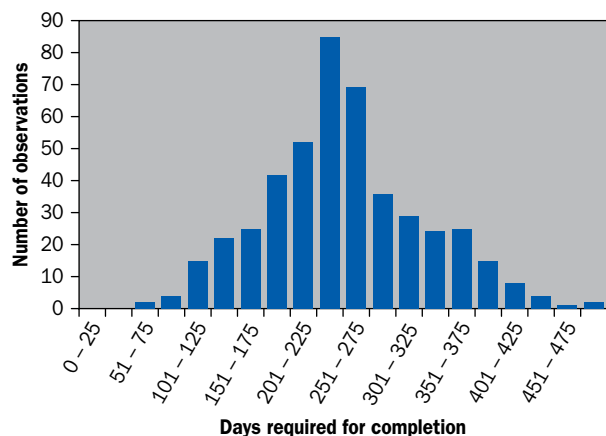


Table 4. **Multiple regression results**

Number of steps	Variable	Step constant	Days added to step constant	Total list time	T-value	P-value	S-vaule	R-sq value	R-sq (adj)
1		61					70.3	28.18	25.6
	CT/CTA scan		87	148	3.31	0.003			
2		79					68.8	33.61	28.7
	CT/CTA scan		79		3.02	0.005			
	Listed elsewhere		-40	118	-1.49	0.149			
3		135					66.1	40.95	34.1
	CT/CTA scan		94		3.56	0.001			
	Listed elsewhere		-57		-2.09	0.046			
	TB test		-67	105	-1.80	0.084			

CT = Computerized tomography
 CTA = Computerized tomographic angiography
 TB = Tuberculosis

process is well above processing under 180 days.

The team calculated a confidence interval (Table 3, p. 13) to show the range of the true mean. This benefits the patient and staff because it lets them understand the true means of the process times. This baseline calculation also opened up a statistical analysis of improvements. Table 3 shows that at a 95% confidence level, the true process cycle time is between 223 and 231 days.

The tools noted earlier were applied to identify the assignable causes leading to the gap between the current performance and the goal. Several reasons—such as surgeon delays, coordinator delays, patient delays/

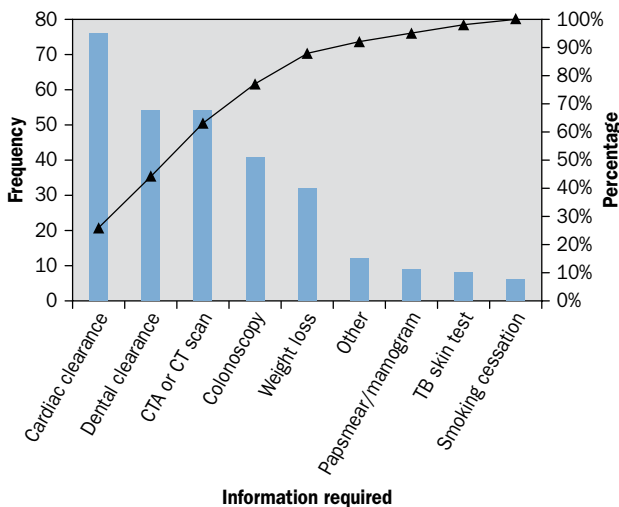
cancellations, communication and patient failure to complete lab tests—contributed to the process taking more than 180 days. After developing the process map and collecting data for 116 active patients, Pareto and five whys analyses showed patient delays in completing lab tests was the top reason for failures. To understand which stage was restraining patients from being listed, the team created a Pareto chart to highlight which labs were incomplete (Figure 4). The results indicated:

- 57% of patients needed a cardiac clearance.
- 40% of patients needed dental clearance.
- 40% of patients needed a computerized tomography (CT) or computerized tomographic angiography (CTA) scan.
- 35% of patients needed a colonoscopy.

The team performed a multiple regression analysis to identify the significant variables that influenced the overall process time. The team used stepwise regression to evaluate the data and the following variables:

- TB skin test.
- Dental clearance.
- Cardiac clearance.
- Colonoscopy.
- Mammogram/pap smear.
- CT or CTA scan.
- Other tests.
- Age.
- Gender.
- Distance.
- Patient listed elsewhere.

Figure 4. **Pareto chart—Incomplete information**



CT = Computerized tomography
 CTA = Computerized tomographic angiography
 TB = Tuberculosis

Table 4 shows the results of the regression analysis. After three steps, 34% (adjusted $r^2 = 0.341$) of the variation in the total process time was explained by whether the patient required a CT test, was listed elsewhere or required a TB exam. This relatively low adjusted r^2 value indicated the model was not a strong predictor of total process time; however, it did offer insight into the variables that were included and those not included in the process.

The Six Sigma team then conducted a FMEA and analyzed the data and system to determine the failure modes, potential effects, severity, occurrences and detection. Key findings and actions taken are discussed later.

A work study was completed to evaluate which tasks occupy most of the transplant coordinator’s workday (Figure 5). The procedure to conduct this work study was based on *Introduction to Statistical Quality Control*.⁴

The coordinator spent most of the time preparing and reviewing patients’ files, which consists of organizing information, filling out and getting required information, updating patients’ medical history and information, reviewing test results of patients and sending patients the necessary information. Other activities included sending and receiving e-mails, checking mail, organizing and scheduling, and reviewing meeting notes. Figure 5 shows that 34% of the coordinator’s time was spent preparing patients’ files. In other words, one-third of the coordinator’s time was spent preparing to see patients.

Analyzing the work study showed that the coordinator had about one hour of idle time each week waiting for other transplant members to complete evaluations of patients. Essentially, this is nonvalue-added time and prevents the coordinator from performing more important tasks. Data entry should be minimal for the coordinator. Figure 6 (p. 16) also displays the coordinator’s percentage of value-added tasks and nonvalue-added tasks. Value-added tasks were identified as patient or provider contact (30% of activities). Nonvalue-added activities were identified as waiting for patients or staff,

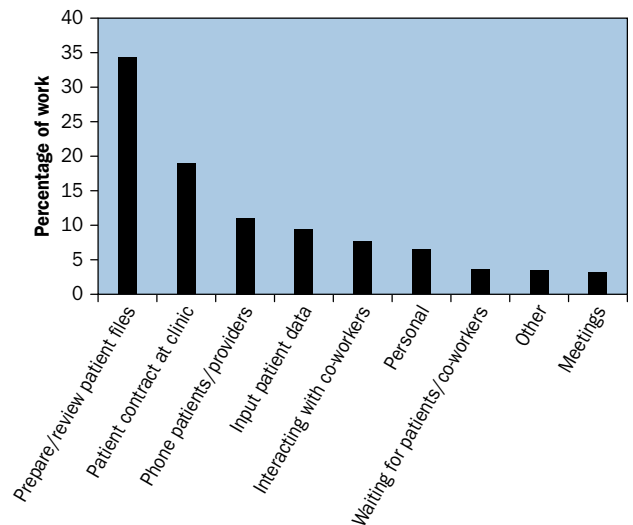
Table 5. **Estimated improvements and initiatives**

	Process issue	Proposed change	Quantified estimated TPTR	Qualified improvement
1	Lack of communication and organization	Use a database	1% (2 days)	Improved staff efficiency and communication
2	No performance tracker	Use a database	0%	Improved staff efficiency and communication
3	Frequency of orientation	Develop a video	7% (16 days)	Improved customer satisfaction
4	Unclear process expectations	Use pre-sheet process overview	1% (2 days)	Improved customer satisfaction
5	Idle time at clinic	Change clinical schedule	0%	Improved use of staff time
6	Unclear requirements	Simplify contract/handout	1% (2 days)	Improved customer satisfaction
7	Frequency of clinical evaluation	Offer more clinic times	8% (18 days)	Improved customer satisfaction
8	Dental lab incompleteness	Offer dental assistance program	2% (5 days)	Improved customer satisfaction
9	No patient continuous monitoring system	Use a database	0%	Improved patient feedback
10	No current standard operating procedure	Create standard operating procedures	0%	Improved staff efficiency and communication

TPTR = Total process time reduction

data input and data review or preparation (70% of activities). The coordinator’s main focus should be working with patients and coordinating labs and tests for them so their information can be presented to the committee for review as quickly as possible. The coordinator’s tasks that should be reduced are: waiting for patients/co-workers, inputting patient data and preparing and reviewing patient files.

Figure 5. **Work study results—transplant coordinator**



Improve

After identifying and analyzing the potential vital Xs, the team created a list of improvement initiatives to address each issue. Meetings and focus groups were held with the patients, surgeons, nurses, transplant coordinators and other staff to review the results and develop a list of improvements and predicted process time reductions (Table 5, p. 15). The following improvements were identified:

- Create and implement a patient database to provide information and generate custom reports (for example, incomplete tests and status).
- Build a tracking system in the database to monitor performance to ensure targets are met based on timelines (tests, process performance and communication between staff and patient).
- Consider using a video for patient orientation instead of presentation (mailed or web-based).
- Consider delaying start of paperwork until patient is signed up for evaluation.
- Consider using a presheet process (an overview of process given at orientation).
- Modify clinical schedule to improve medical staff's efficiency and reduce patient cycle time. Establish an evaluation so the coordinator only has to see the patient at the end of the process. This would allow the coordinator to spend less time at the clinical evaluation and more time to contact patients and break barriers. Consider moving the social worker into different office to conduct the evaluation.
- Give a simplified handout or contract describing

Figure 6. **Value-added pie chart**

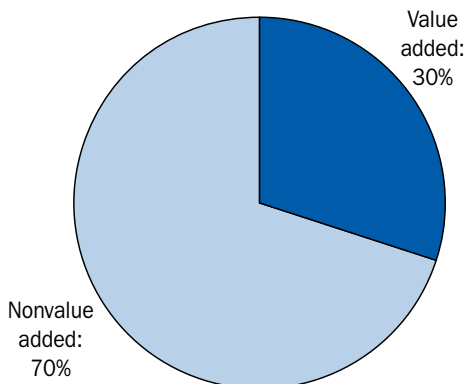


Table 6. **Combined test results**

Process cycle failures	Baseline	Test results
Defect rate	85.1 %	26.4%
DPMO	851,000	264,000
Total annual savings		\$22,000
Sigma level	0.46	2.2

DPMO = defects per million opportunities

the process and expectations with a timeline at the end of clinical evaluation.

- Consider offering clinical evaluations on one additional day of the week because of the long time it takes between orientation and clinical evaluation.
- Develop a dental assistance program to identify potential doctors and costs, and assist patients with scheduling.
- Consider a continuous monitoring system using the database. Send the report to the patient to verify information at a determined interval (two weeks or four months).
- Develop standard operating procedures (SOPs) for the process to ensure uniformity and consistent work.

The transplant team decided to pursue building a database, which will track important data and performance measures. To improve the clinical evaluation process, the team modified the patient schedule by rescheduling the financial officer and social worker to see patients after the doctor and coordinator are finished with them. These activities can be done in a different room.

The team didn't have enough staff to offer clinical evaluations on one additional day each week, but the staff did agree to add another patient to each day evaluations are offered. They also agreed to work with different dental offices to reduce dental costs for patients who cannot afford dental care.

The transplant team implemented a solution center and created a position to handle incoming calls about the transplant process. This required someone to look up information in the database and answer common questions. If the employee cannot answer a question, he or she can direct patients to an appropriate staff member. This allows coordinators more time to focus on helping patients become listed faster.

The solution center also made the process more personal to the patient, because the patient only needs one phone number to call for questions and can avoid the frustration of calling several places. The solution

center also serves as a barrier breaker and further personalizes UTMC's medical services.

Table 5 shows a total process cycle time reduction of 63 days—a 27.8% drop—in the current cycle time of 227 days to 163 days. Improvements were implemented and results shared daily with the medical staff and administration. After meeting with all stakeholders, a standardized process was created and documented. The goals of the standardized process were to mistake-proof and streamline the process from the patient's viewpoint. The process was tracked, and process cycle time and standard deviation were measured for each patient for one year. The mean cycle time was reduced by 28.2% (64 days), from 227 days to 163 days, and the standard deviation was reduced from 45 days to 27 days.

To validate the process improvements, a process capability study was completed on the process cycle time for the new system. Hypothesis tests were also conducted on the difference between the means and variances for the previous process and the new process.

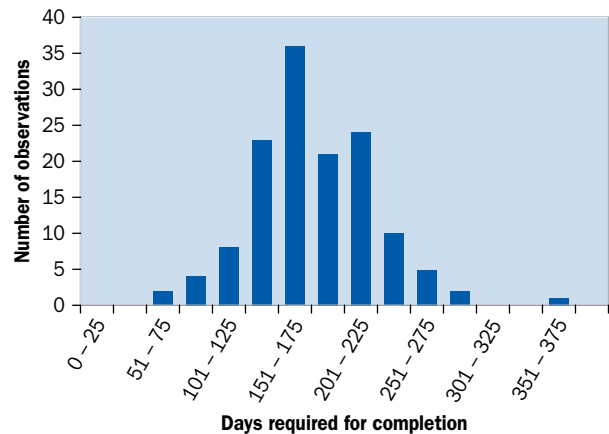
From a process capability standpoint, the process has significantly improved. The new process is much more capable of performing within specifications (cycle times within 180 days) as calculated with a C_{pk} value of 0.21, up from -0.34 with the previous system. Work is still needed to raise the C_{pk} to a value greater than 1.

Assuming a normal distribution with a mean of 163 days and standard deviation of 27 days, 73.6% of all cycle times will be within the target process time of 180 days or less. To validate this normality assumption, a histogram was created (Figure 7) for the processing times after the improvement initiatives were implemented. Based on the expected bell shaped curve, the normality assumption appears valid.


Training courses and SOPs were developed for all processes. As a result of the improvements, process cycle time failures (defined as greater than 180 days) were reduced by 68.9%—from 851,000 to 264,000 defects per million opportunities. This reflects an annual savings of \$22,000 from reduced administrative costs and photocopies (see Table 6).

To ensure the process performs within the acceptable limits and to continue to drive down the cycle time, performance is monitored on an ongoing basis. To achieve control status, \bar{x} and \bar{r} charts (a tool that tracks defects over time) were used.⁵ In addition, key staff members meet weekly to discuss performance and generate new improvement solutions. These meetings involve a review of process times, patient surveys and adherence to SOPs.

Figure 7. **Histogram of completion times for the improved process**



Applied elsewhere

Six Sigma is an effective way to identify root causes of problems using data-driven approaches in healthcare. As a direct result of this research, patients will receive life-saving transplants earlier. Complicating factors in conducting this project included maintaining strict patient confidentiality (Health Insurance Portability and Accountability Act laws) and coordinating meeting times within the surgeons and nurses schedules. This method and approach applied in this research could be used to improve renal transplant centers around the world, as well as other transplant centers for different organs. 

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