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REGISTRY OF  
TRANSPLANT  
RECIPIENTS

# Use of SRTR CUSUM charts: When should I hit the panic button?

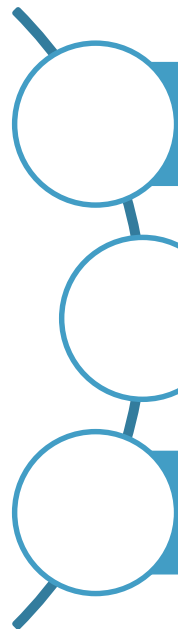


Jon Snyder, PhD

Nicholas Salkowski, PhD

Andrew Wey, PhD

# Overview

- 
- Background & Overview - Snyder
  - Posttransplant CUSUMs - Salkowski
  - Pretransplant CUSUMs - Wey

# Transplant Center Quality Assessment Using a Continuously Updatable, Risk-Adjusted Technique (CUSUM)

Axelrod et al. Am  
J Transplant  
2006; 6:313-323.

**D. A. Axelrod<sup>a</sup>, M. K. Guidinger<sup>b</sup>, R. A. Metzger<sup>c</sup>,  
R. H. Wiesner<sup>d</sup>, R. L. Webb<sup>e</sup> and R. M. Merion<sup>e,f,\*</sup>**

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<sup>b</sup>Scientific Registry of Transplant Recipients (SRTR)/University Renal Research and Education Association (URREA), Ann Arbor, MI, USA

<sup>c</sup>TransLife-Florida Hospital Medical Center, Orlando, FL, USA

<sup>d</sup>Mayo Clinic College of Medicine, Rochester, MN, USA

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## Introduction

The provision of timely, risk-adjusted outcome information is crucial to improving clinical care processes. Frequent, real time monitoring of surgical outcomes allows physician leaders to validate clinical process improvements or to identify potentially correctable practice patterns. While standard statistical techniques, including average mortality, risk-adjusted average mortality and multivariate modeling, can be used to identify changing levels of performance at a national level, they have been found to be relatively insensitive to small changes in outcomes that occur at the hospital level (1–4). Furthermore, over time, these methods are likely to produce false positive results due to the need for multiple comparisons of the same data.

## Meeting Report

# Report of a Consensus Conference on Transplant Program Quality and Surveillance

**B. L. Kasiske<sup>a,b,\*</sup>, M. A. McBride<sup>c</sup>, D. L. Cornell<sup>d</sup>,  
R. S. Gaston<sup>e</sup>, M. L. Henry<sup>f</sup>, F. D. Irwin<sup>g</sup>,  
A. K. Israni<sup>a,b,h</sup>, N. W. Metzler<sup>i</sup>, K. W. Murphy<sup>j</sup>,  
A. I. Reed<sup>k</sup>, J. P. Roberts<sup>l</sup>, N. Salkowski<sup>b</sup>,  
J. J. Snyder<sup>b,h</sup> and S. C. Sweet<sup>m</sup>**

<sup>a</sup>Department of Medicine, Hennepin County Medical  
Center, University of Minnesota, Minneapolis, Minnesota

sess outcomes at small-volume transplant programs should be developed. More data on waiting list risk and outcomes should be provided. Monitoring and reporting of short-term living donor outcomes should be enhanced. Overall, there was broad consensus that substantial improvement in reporting outcomes of transplant programs in the United States could and should be made in a cost-effective manner.

## Meeting Report

# Report of Program C

I.4. Provide transplant centers, the MPSC and CMS with tools such as the cumulative sum (CUSUM) technique and tools to allow subgroup analysis to facilitate quality assessment and performance improvement.

# plant

**B. L. Kasiske<sup>a,b,\*</sup>, R. S. Gaston<sup>e</sup>, M. L. Henry<sup>f</sup>, R. D. Hwang<sup>g</sup>,  
A. K. Israni<sup>a,b,h</sup>, N. W. Metzler<sup>i</sup>, K. W. Murphy<sup>j</sup>,  
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transplant programs in the United States could and  
should be made in a cost-effective manner.

## Special Article

# New Quality Monitoring Tools Provided by the Scientific Registry of Transplant Recipients: CUSUM

**J. J. Snyder<sup>1,\*</sup>, N. Salkowski<sup>1</sup>, D. Zaun<sup>1</sup>,  
S. N. Leppke<sup>1</sup>, T. Leighton<sup>1</sup>, A. K. Israni<sup>1,2</sup>  
and B. L. Kasiske<sup>1,2</sup>**

<sup>1</sup>*Scientific Registry of Transplant Recipients, Minneapolis  
Medical Research Foundation, Minneapolis, MN*

<sup>2</sup>*Department of Medicine, Hennepin County Medical  
Center, Minneapolis, MN*

\*Corresponding author: Jon J. Snyder, [jsnyder@srtr.org](mailto:jsnyder@srtr.org)

**specific report; SPC, statistical process control; SRTR,  
Scientific Registry of Transplant Recipients; STAC,  
SRTR Technical Advisory Committee**

**Received 22 August 2013, revised 18 November 2013  
and accepted for publication 16 December 2013**

## Introduction

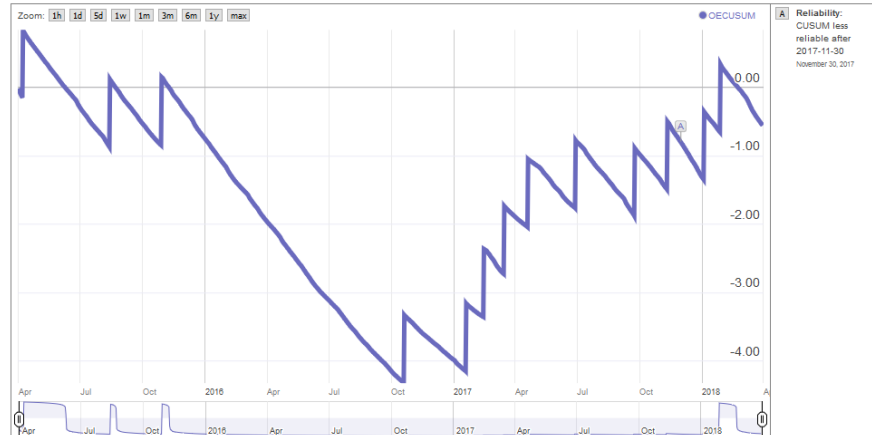


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TRANSPLANT RECIPIENTS

# CUSUMs (cumulative sum) are currently provided for the following metrics:

## Posttransplant Graft/Patient Survival

Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



## Offer Acceptance





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# Post-transplant CUSUMs

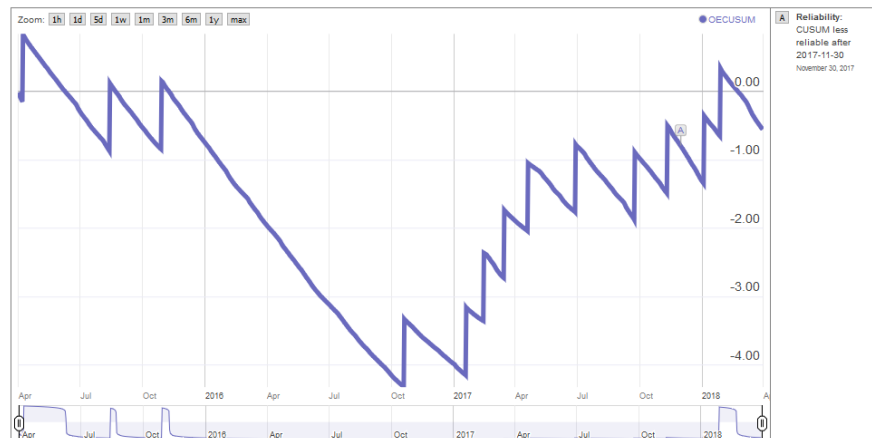
Nicholas Salkowski, PhD



# One-Sided vs. Two-Sided CUSUM Charts

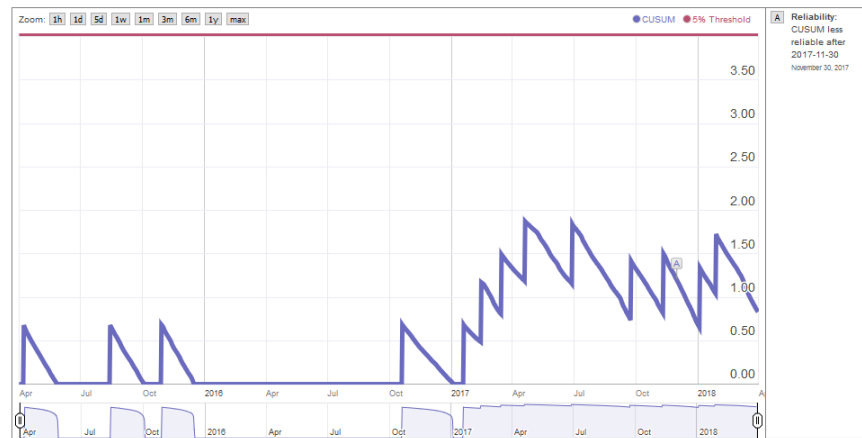
## Two-Sided (Observed-Expected)

Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



## One-Sided (statistical test)

One-Sided CUSUM: All Donor Adult One-Year Graft Failure



## Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



Three-year period

## Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



# How the two-sided chart is calculated

- On every day of the three-year period, any patient who is within 1 year of their transplant is included in the chart on that day.
- For each day, we calculate two numbers:
  - The number of graft failures reported on that day (O)
  - The number of expected (E) graft failures on that day for the patients who were at risk on that day. This is based on the risk adjustment models.
- The CUSUM value is arrived at by summing the O and E values from the start of the chart up until the specific day; thus the cumulative sum.

# Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



**Y-Axis:**  
Observed – Expected  
(O-E)

-1 = 1 fewer failure than  
expected  
1 = 1 more graft failure  
than expected

## Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



**Trending down:  
Better than expected  
rates of failure**

## Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



# Accompanying One-Sided CUSUM

One-Sided CUSUM: All Donor Adult One-Year Graft Failure

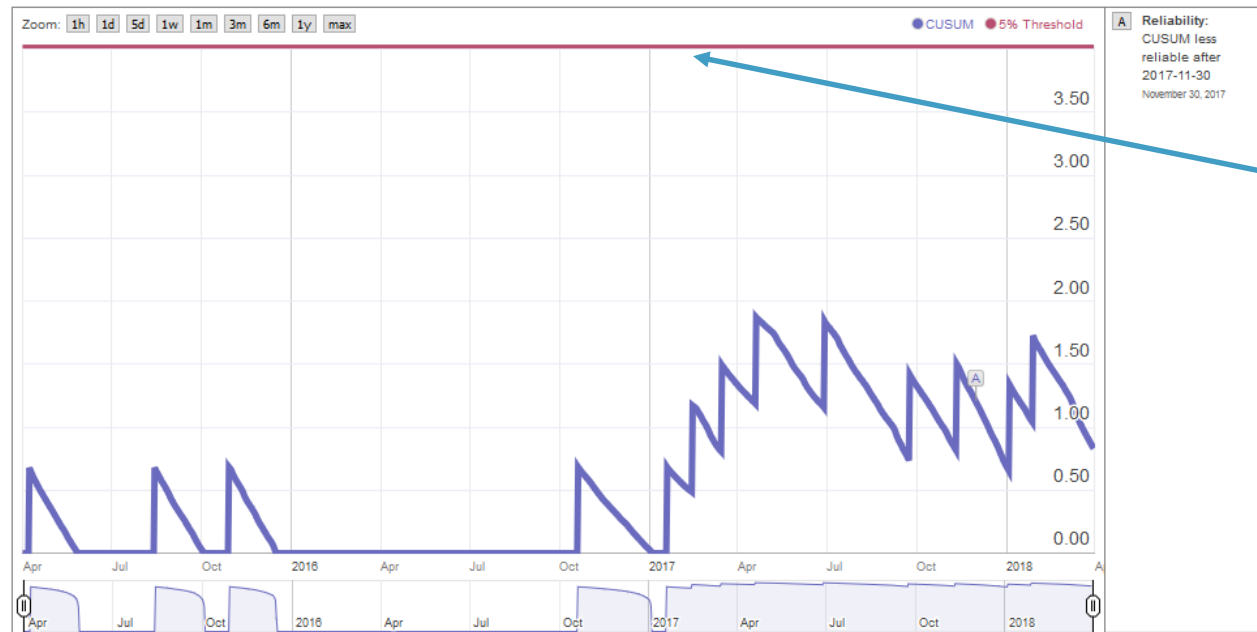


**Attempts to discern whether the observed trends are “statistically significant” or perhaps just random noise.**



# Accompanying One-Sided CUSUM

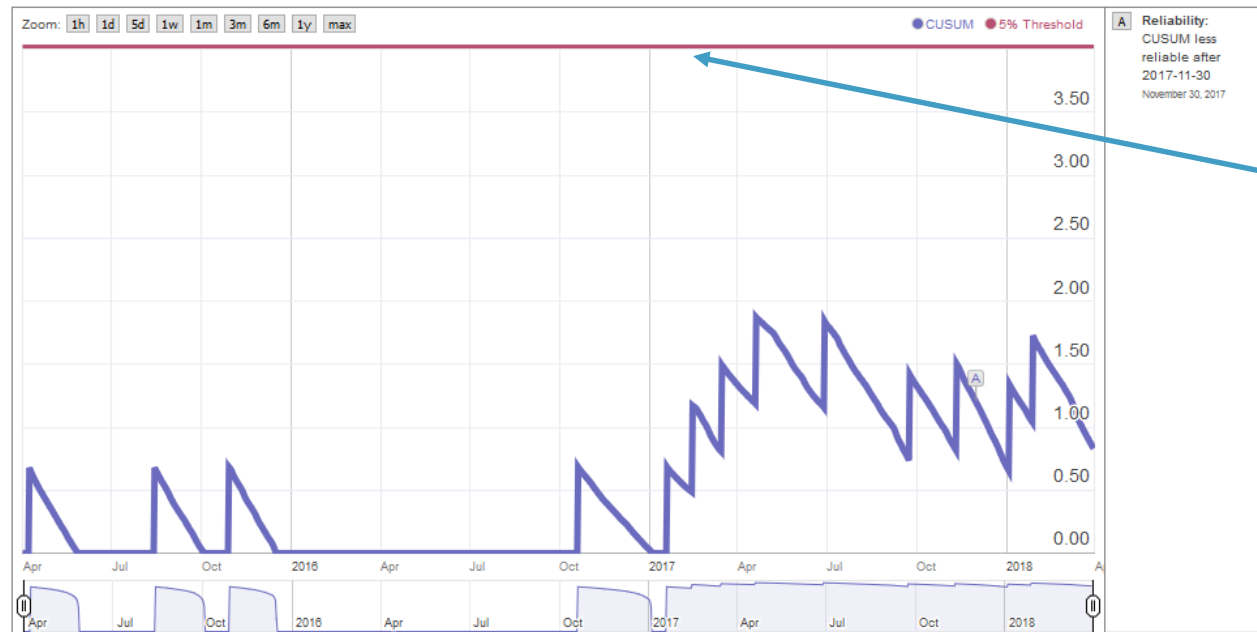
One-Sided CUSUM: All Donor Adult One-Year Graft Failure



Has a red “5% Threshold line at the top of the chart. If the line hits the threshold, we conclude there is sufficient evidence of a real trend.

# Accompanying One-Sided CUSUM

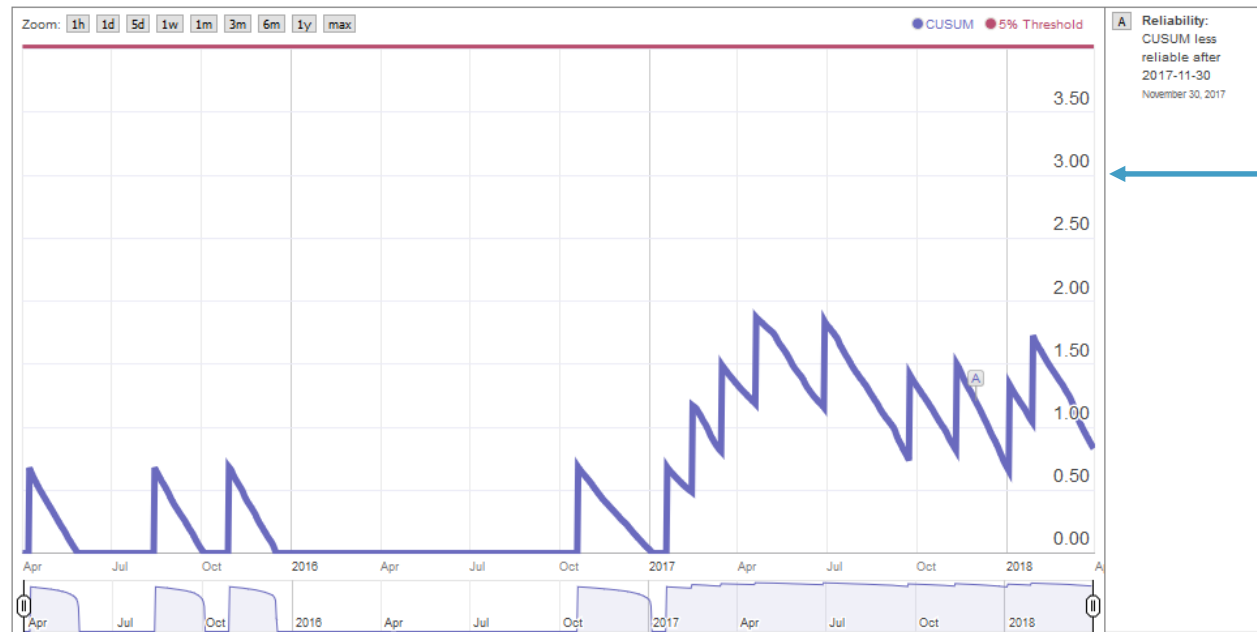
One-Sided CUSUM: All Donor Adult One-Year Graft Failure



It is called the “5% threshold” because there is about a 5% chance of a false positive if the chart hits this line.

# Accompanying One-Sided CUSUM

One-Sided CUSUM: All Donor Adult One-Year Graft Failure



Y-axis is more difficult to interpret (i.e., don't worry about the value). It is the value of the CUSUM test statistic. Importantly, it is not O-E.

2018-05-01

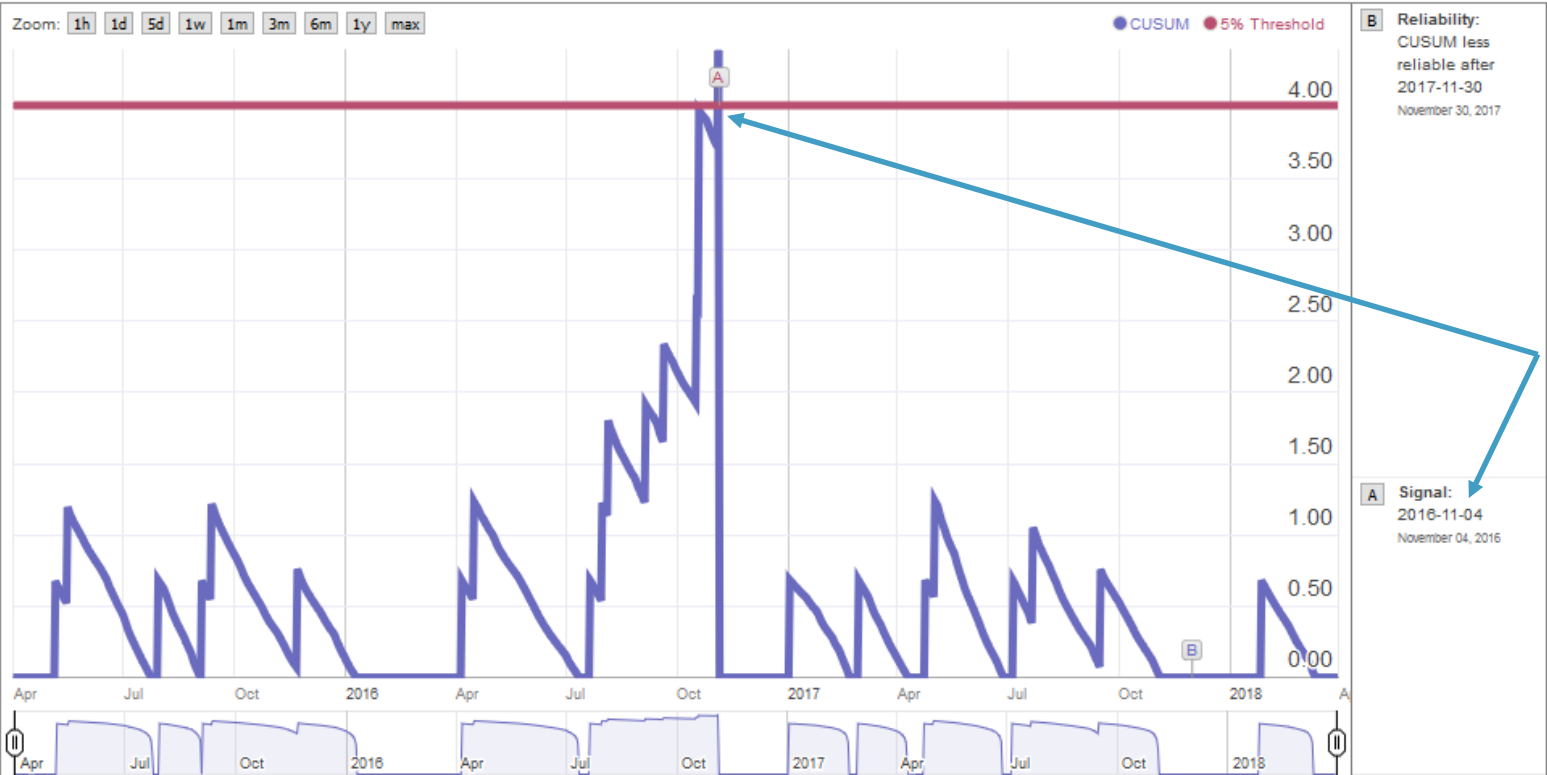
Observed - Expected CUSUM: All Donor Adult One-Year Graft Failure



O-E = 6.75

The liver program experienced almost 7 more failures than expected over the three-year period. Is this trend statistically significant?

One-Sided CUSUM: All Donor Adult One-Year Graft Failure



**This chart signaled on 11/4/2016. This is when the chart had accumulated enough evidence that the observed trend was more than statistical noise (with a 5% chance this is a false positive).**



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# Offer Acceptance CUSUM charts

Andrew Wey, PhD

# What is offer acceptance?

Offer acceptance is the propensity of programs to accept an offer compared to national acceptance practices after accounting for candidate and donor characteristics.

In other words, is a program more or less likely to accept a given offer?

# Why care about offer acceptance?

Offer acceptance practices impact allocation efficiency: Above average acceptance practices were associated with higher organ yield (more transplants per donor) in kidney, liver, lung, and heart transplant.

Offer acceptance impacts the probability of waitlist mortality: Programs with above average offer acceptance transplant candidates at a higher rate, which lowers the probability of a candidate dying on the waiting list.



# SRTR resources for offer acceptance

SRTR provides several resources for programs interested in offer acceptance practices:

- Program-specific reports summarize acceptance practices over a year, includes figures to illustrate acceptance relative to other programs
- CUSUM reports provide a trajectory of acceptance practices over time and a separate summary of recent acceptance practices within certain subgroups
- An OPO offer acceptance report summarizes the acceptance practices of programs for certain categories that may be hard-to-place

# SRTR resources for offer acceptance

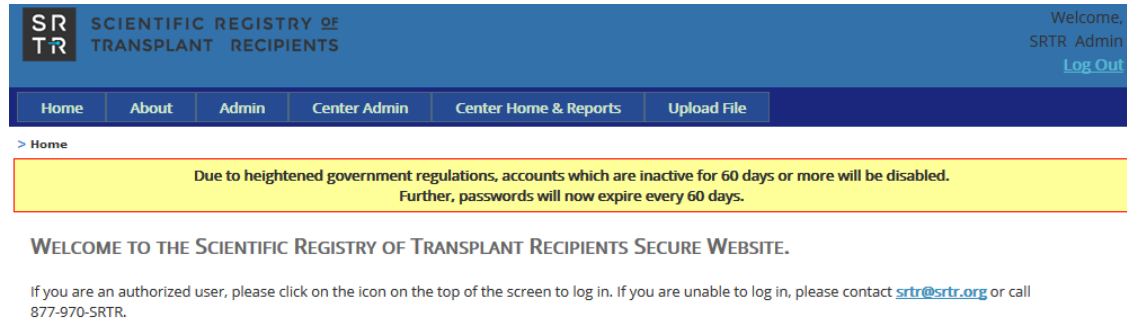
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# Audience poll...

How many people use the offer acceptance CUSUM reports?

# Accessing offer acceptance CUSUMs



The screenshot shows the SRTR Secure Website homepage. At the top, the SRTR logo is on the left, and the text "SCIENTIFIC REGISTRY OF TRANSPLANT RECIPIENTS" is in the center. On the right, it says "Welcome, SRTR Admin" with a "Log Out" link. Below this is a navigation bar with links: Home, About, Admin, Center Admin, Center Home & Reports, and Upload File. A yellow warning box states: "Due to heightened government regulations, accounts which are inactive for 60 days or more will be disabled. Further, passwords will now expire every 60 days." Below the warning, it says "WELCOME TO THE SCIENTIFIC REGISTRY OF TRANSPLANT RECIPIENTS SECURE WEBSITE." and provides instructions for authorized users to log in or contact support at [srtr@srtr.org](mailto:srtr@srtr.org) or call 877-970-SRTR.

SRTR SCIENTIFIC REGISTRY OF TRANSPLANT RECIPIENTS

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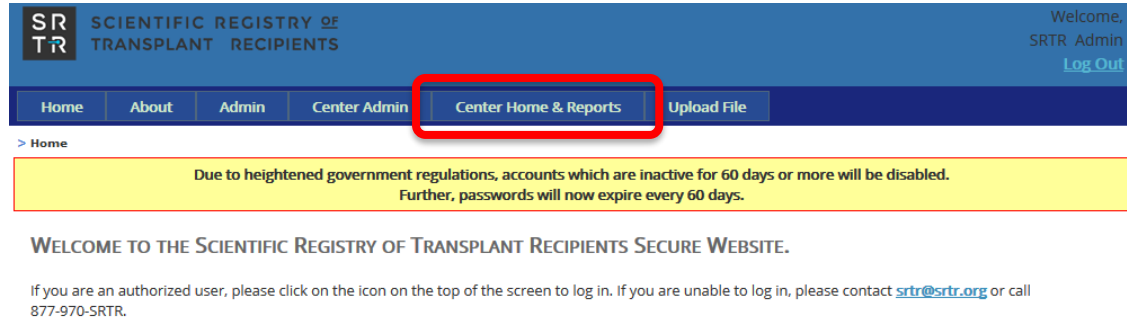
> Home

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WELCOME TO THE SCIENTIFIC REGISTRY OF TRANSPLANT RECIPIENTS SECURE WEBSITE.

If you are an authorized user, please click on the icon on the top of the screen to log in. If you are unable to log in, please contact [srtr@srtr.org](mailto:srtr@srtr.org) or call 877-970-SRTR.

# Accessing offer acceptance CUSUMs



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# Accessing offer acceptance CUSUMs

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> [Home](#) > [Center Home](#) > [Tools](#)

Due to heightened government regulations, accounts which are inactive for 60 days or more will be disabled. Further, passwords will now expire every 60 days.

CUSUM Charts Guide

SRTR GUIDE TO UNDERSTANDING CUSUM CHARTS

[Go to your CUSUM charts](#)

[Click here](#) for a statement from the SRTR on the use of CUSUM charts.

OVERVIEW

CUSUM (short for "cumulative sum") is a quality control method used in statistical analysis. CUSUM charting techniques are used to detect a change in a process. A CUSUM chart is constructed by plotting a transplant program's performance over time. The chart consists of a line with a point plotted for each calendar day. On each day that no patient in that program dies or experiences a graft failure, the CUSUM line goes down. Conversely, on each day that a patient in that program dies or experiences a graft failure, the line goes up. If patients in the program die at the expected rate, the line on the CUSUM chart hovers around zero. If patients in the program die at a higher than expected rate, the line goes up over time. Thresholds can be set to indicate when a program should react to the data in the chart, for example by initiating an internal review to determine whether action should be taken. Following recommendations from the OPTN-SRTR consensus conference (full conference materials can be reviewed at: <http://www.srtr.org/cctpgs/default.aspx>), SRTR is providing monthly CUSUM charts for transplant programs in the United States. These charts are posted on the SRTR secure website, and they are to be used solely to support quality monitoring initiatives within each program. This guide will help programs correctly interpret the information provided in these charts.

The links at the beginning and end of this overview will take you to your program's CUSUM report repository. Here you will see links to the monthly CUSUM reports. SRTR will provide monthly updates to the CUSUM charts in an effort to provide programs with the most up-to-date information possible. The most recent 3 months of charts are provided on the website so programs may review recent historical charts if they wish.

UNDERSTANDING YOUR PROGRAM'S CUSUM CHARTS

PERIOD OF TIME COVERED BY THE CHARTS

Each CUSUM report contains information from the most recent 3-year period. The most recent month covered by each chart is 2 months prior to the month in which the report was generated. For example, reports released in December 2013 will contain information through October 2013. Each report covers a full 3-year period prior to that month, e.g., November 2010 through October 2013. Each chart is accompanied by a note indicating that data might be less reliable in the most recent 4-month period given lags in data reporting. Timely reporting by programs will help ensure the CUSUM data are as accurate and up to date as possible.

OUTCOMES MONITORED IN THE CHARTS

SRTR provides information on the following transplant outcomes:

# Accessing offer acceptance CUSUMs

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> [Home](#) > [Center Home](#) > [Tools](#) > CUSUM Charts List

Due to heightened government regulations, accounts which are inactive for 60 days or more will be disabled.  
Further, passwords will now expire every 60 days.

CUSUM Chart List

Houston Methodist Hospital, Houston, TX  
Center Code: TXMH

Special Announcement Regarding CUSUMs

The Organ Procurement Transplantation Network (OPTN) experienced an unanticipated loss of its source for supplemental information identifying whether a patient is currently living or deceased. In April 2018, OPTN began receiving this information again, and is in the process of confirming a large volume of information. All patient status information that is ultimately confirmed will then be incorporated into the OPTN database and will be used in OPTN and SRTR data analyses and reporting, including the CUSUMs.

As soon as the updated information becomes available, data updates will be implemented to the CUSUMs. Thank you for your patience as we work with our partners to resolve this issue.

CUSUM Error Identified and Resolved

An error was identified in the CUSUM charts, and has since been resolved. Read more about the issue [here](#). Thank you for your patience as we worked to resolve this issue. (Posted 2/22/2018 at 9:33 a.m. CDT)

[Kidney](#) [Liver](#) [Heart](#) [Lung](#)

Kidney

September 2018

Cohort Age	Type	Interactive CUSUM Charts (Google Vis)	Printable Static CUSUM Charts (PNG)	Data Tables (HTML)
Adult	Graft Survival	<a href="#">Go</a>	<a href="#">Go</a>	<a href="#">Go</a>
	Patient Survival	<a href="#">Go</a>	<a href="#">Go</a>	<a href="#">Go</a>
Pediatric	Graft Survival	No Report	No Report	No Report
	Patient Survival	No Report	No Report	No Report
Adult and Pediatric	Offer Acceptance	<a href="#">Go</a>	No Report	No Report

August 2018


Cohort Age	Type	Interactive CUSUM Charts (Google Vis)	Printable Static CUSUM Charts (PNG)	Data Tables (HTML)
Adult	Graft Survival	<a href="#">Go</a>	<a href="#">Go</a>	<a href="#">Go</a>



# Offer acceptance report

**Offer Acceptance Report**

AboutCUSUM Charts ▾Across Donor Characteristics

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**Offer Acceptance CUSUM Report**

Center Code:  
SRTR

Transplant Program (Organ):  
Liver

Data From:  
07/31/2018

Cohort Start:  
01/01/2018

Cohort End:  
04/30/2018

Feedback?:  
[SRTR@SRTR.org](mailto:SRTR@SRTR.org)  
1.877.970.SRTR (7787)  
<http://www.srtr.org/>

The offer acceptance report for the liver program at SRTR. The report provides detailed information on offer acceptance behavior across time (CUSUM Charts) and important subgroups, e.g., donor quality (Across Donor Characteristics). The reported offer acceptance behavior is relative to the national acceptance behavior after adjusting for donor quality and candidate characteristics.

The report evaluates the acceptance behavior for offers from donors recovered between 01/01/2018 and 04/30/2018. The expected number of acceptances are based on the offer acceptance model estimated with offers from donors recovered between 07/01/2016 and 06/30/2017.


# Offer acceptance report

Offer Acceptance Report

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The o  
and in

Expected-Observed CUSUM  
One-Sided CUSUM

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Expected-Observed CUSUM

One-Sided CUSUM

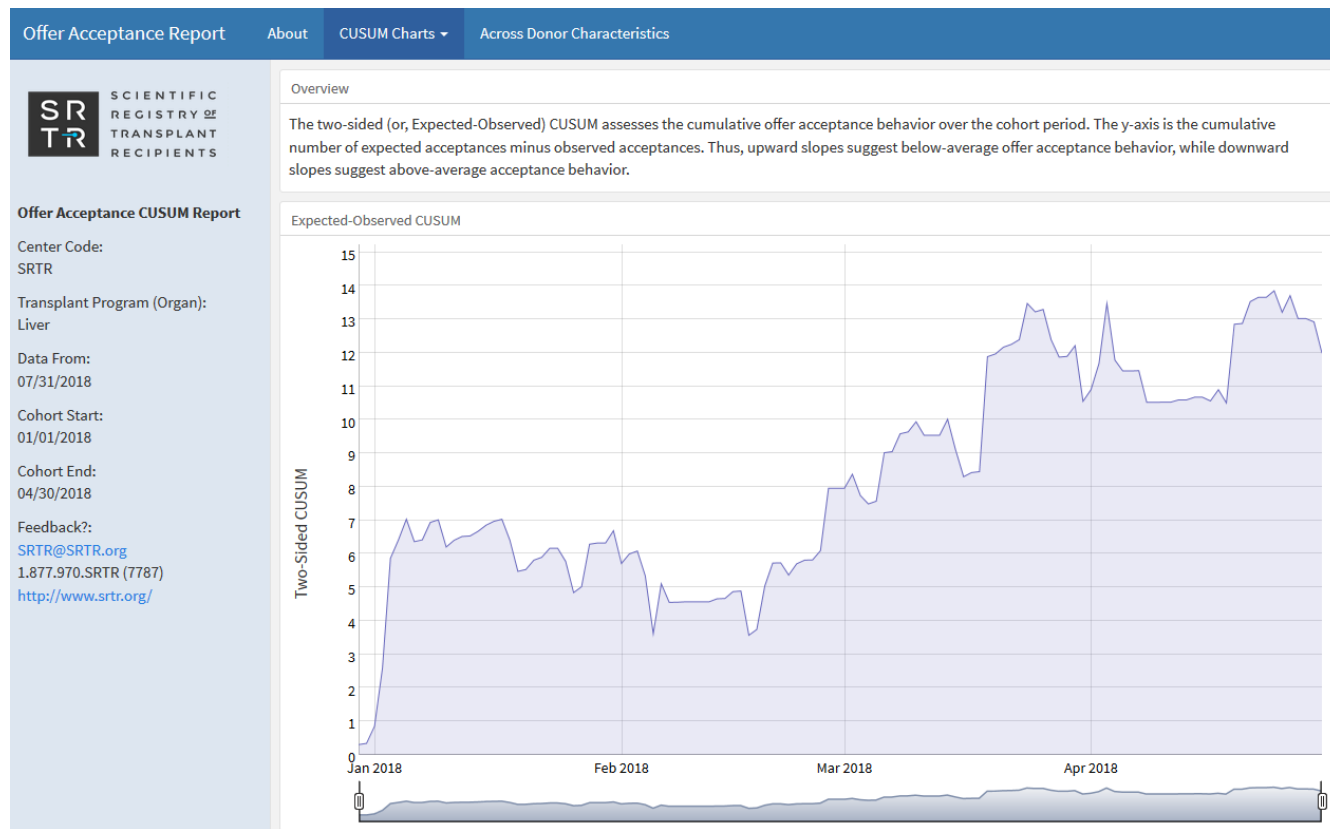
The offer acceptance report is a program at SRTR. The report provides detailed information on offer acceptance behavior across time (CUSUM Charts) and in quality (Across Donor Characteristics). The reported offer acceptance behavior is relative to the national acceptance behavior after adjusting for donor quality and candidate characteristics.

The report evaluates the acceptance behavior for offers from donors recovered between 01/01/2018 and 04/30/2018. The expected number of acceptances are based on the offer acceptance model estimated with offers from donors recovered between 07/01/2016 and 06/30/2017.



# Offer acceptance report:

## Expected-Observed (Two-sided) CUSUM



# Offer acceptance report:

## Expected-Observed (Two-sided) CUSUM

There was a period of below average acceptance but was it out significantly below expected?

We can use the one-sided CUSUM to help answer this question






# Offer acceptance report

Offer Acceptance Report

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Across Donor Characteristics



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Offer Acceptance CUSUM Report

Center Code:  
SRTR

Transplant Program (Organ):  
Liver

Data From:  
07/31/2018

Cohort Start:  
01/01/2018

Cohort End:  
04/30/2018

Feedback?:  
[SRTR@SRTR.org](mailto:SRTR@SRTR.org)  
1.877.970.SRTR (7787)  
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Expected-Observed CUSUM

One-Sided CUSUM

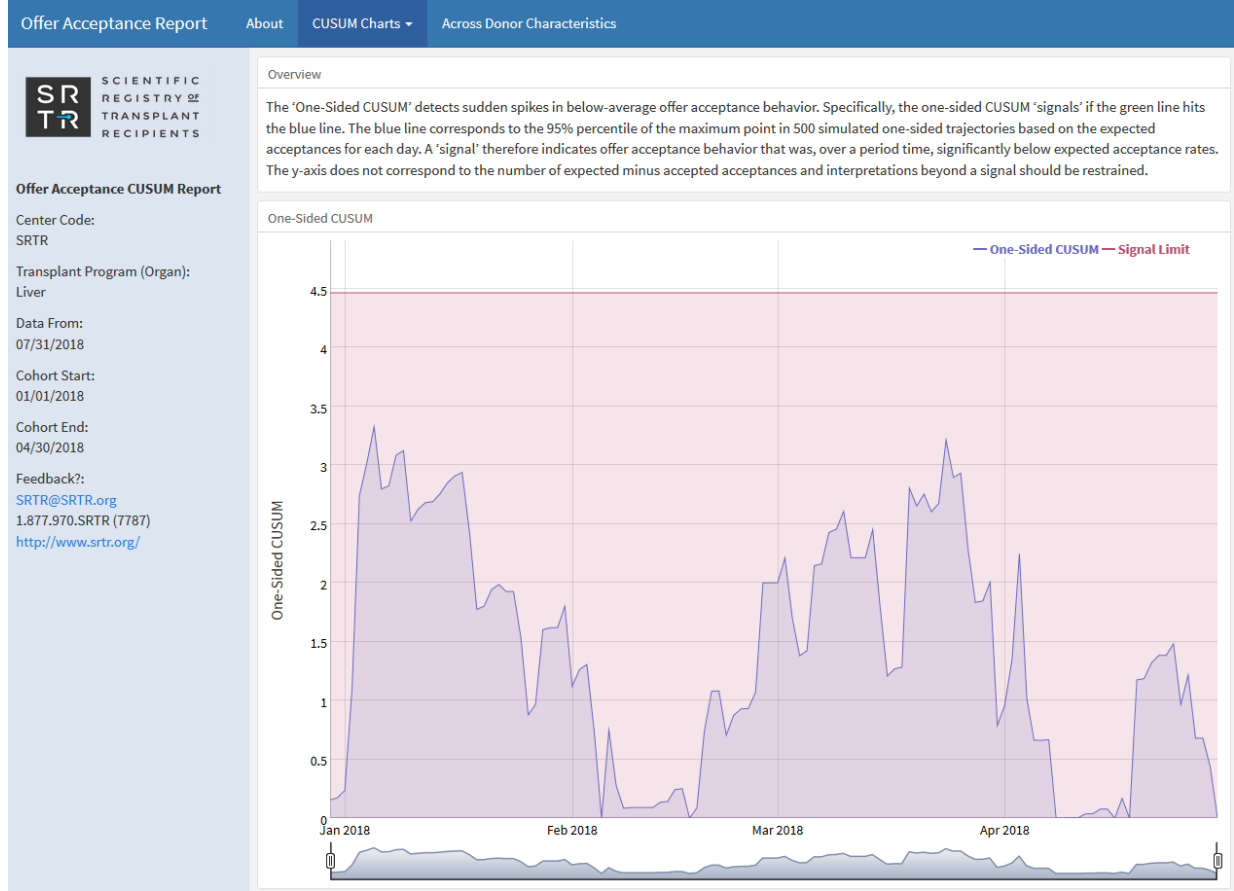
The offer acceptance report for the SRTR program at SRTR. The report provides detailed information on offer acceptance behavior across time (CUSUM Charts) and in quality (Across Donor Characteristics). The reported offer acceptance behavior is relative to the national acceptance behavior after adjusting for donor quality and candidate characteristics.

The report evaluates the acceptance behavior for offers from donors recovered between 01/01/2018 and 04/30/2018. The expected number of acceptances are based on the offer acceptance model estimated with offers from donors recovered between 07/01/2016 and 06/30/2017.



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## One-sided CUSUM



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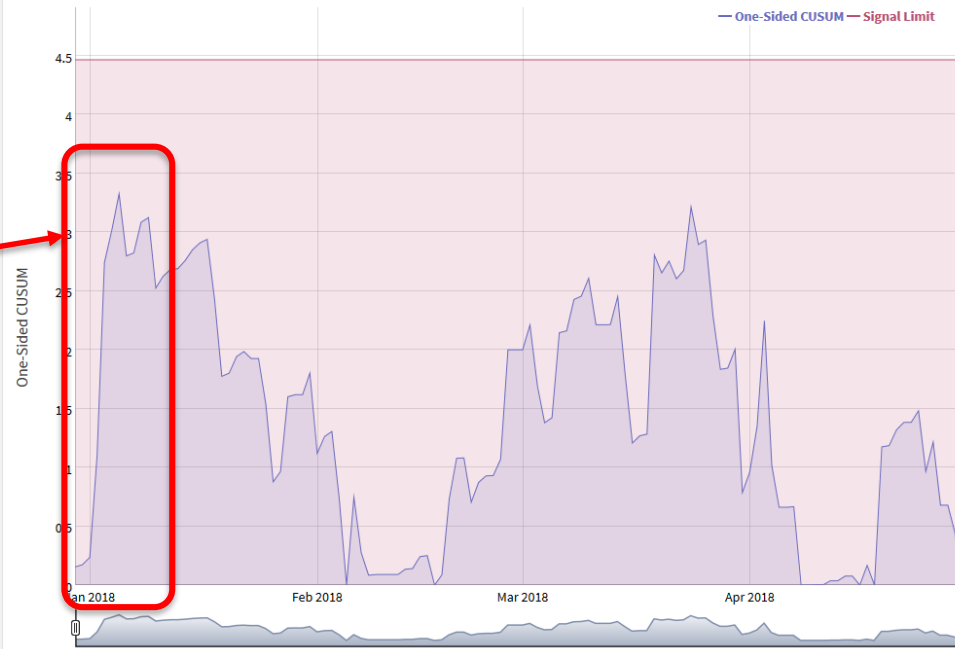
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## Overview

The 'One-Sided CUSUM' detects sudden spikes in below-average offer acceptance behavior. Specifically, the one-sided CUSUM 'signals' if the green line hits the blue line. The blue line corresponds to the 95% percentile of the maximum point in 500 simulated one-sided trajectories based on the expected acceptances for each day. A 'signal' therefore indicates offer acceptance behavior that was, over a period time, significantly below expected acceptance rates. The y-axis does not correspond to the number of expected minus accepted acceptances and interpretations beyond a signal should be restrained.

## One-Sided CUSUM



# Offer acceptance report:

## One-sided CUSUM

The initial spike is visible in the one-sided CUSUM but it does not reach the signal limit at the top of the graph. This indicates that acceptance was not 'out of control' at the beginning of the period.


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The offer acceptance report for the liver program at SRTR. The report provides detailed information on offer acceptance behavior across time (CUSUM Charts) and important subgroups, e.g., donor quality (Across Donor Characteristics). The reported offer acceptance behavior is relative to the national acceptance behavior after adjusting for donor quality and candidate characteristics.

The report evaluates the acceptance behavior for offers from donors recovered between 01/01/2018 and 04/30/2018. The expected number of acceptances are based on the offer acceptance model estimated with offers from donors recovered between 07/01/2016 and 06/30/2017.



# Offer acceptance report

## Offer Acceptance Report

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#### Overview

The program-specific offer acceptance behavior is presented for important subcategories of donors ("Donor Characteristics"). For each category, the offer acceptance ratio is estimated by two plus the number of acceptances divided by two plus the number of expected acceptances. The offer acceptance ratio is interpreted as the relative increase ( $>1$ ) or decrease ( $<1$ ) in the offer acceptance compared to national expectations. The history of acceptance is determined by a combination of the offer acceptance ratio and the number of expected acceptances and ranges from below average to above average acceptance.

#### Offer Acceptance Ratios Across Donor Characteristics

Donor Characteristics	History of Acceptance	Number of Offers	Number of Acceptances	Expected Acceptances	Offer Acceptance Ratio
Overall	Somewhat Below Average	4088	42	53.99	0.79
DCD Donor	Somewhat Above Average	673	7	3.30	1.70
PHS Increased Infectious Risk	Average	594	11	11.39	0.97
HCV+	Average	103	2	2.24	0.94
Donor Age ( $> 40$ )	Somewhat Below Average	2009	21	24.90	0.86
Over 50 Offers	Below Average	3077	3	13.11	0.33
Over 500 Miles Away	Average	1060	8	8.95	0.91
Weekend	Somewhat Above Average	779	11	8.71	1.21



SCIENTIFIC REGISTRY OF  
TRANSPLANT RECIPIENTS

# Offer acceptance report

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# Offer acceptance report

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About CUSUM Charts Across Donor Characteristics					
<div><div><div>SR</div><div>TR</div></div><div>SCIENTIFIC REGISTRY OF TRANSPLANT RECIPIENTS</div></div> <div><div>Offer Acceptance CUSUM Report</div><div>Center Code: SRTR</div><div>Transplant Program (Organ): Liver</div><div>Data From: 07/31/2018</div><div>Cohort Start: 01/01/2018</div><div>Cohort End: 04/30/2018</div><div>Feedback?: <a href="mailto:SRTR@SRTR.org">SRTR@SRTR.org</a> 1.877.970.SRTR (7787) <a href="http://www.srtr.org/">http://www.srtr.org/</a></div></div>					
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# Offer acceptance reports

The offer acceptance reports provide information on several different aspects of acceptance practices:

- Identifies changes in acceptance practices at different times during the year.
- Identifies above or below average acceptance practices for different categories of offers.

# References

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Wey et al., "Heart and lung organ offer acceptance practices of transplant programs are associated with waitlist mortality and organ yield," *American Journal of Transplantation*, 2018.



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