**Transcripts for Video on Risk Adjusted Control Chart**

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It's important to distinguish the need for risk-adjusted export chart from the traditional export chart. Those traditional export charts are constructed without risk adjustment.

The purpose of export chart is to detect if the process has improved beyond historical levels, assumes we have been serving the same type of patients historically as now. In contrast, the purpose of risk-adjusted export chart is to detect if the process has improved beyond what can be expected from the patients' conditions. Are we better than the average or expected values?

The data needed for this type of analysis include continuous outcome measures over time. The outcome must be measured on an interval scale where we could multiply or divide the score assigned to the outcome. In addition to the outcome over time, we also need risk or expected outcomes for each patient in each time period. Note that these data are needed for each patient and not just for each time period. Risk data can be calculated from patients' comorbidity as in the multi-morbidity index, from clinicians' consensus, or even from patients' self-insight into their own fate.

I will demonstrate the risk-adjusted export child by analyzing these data. The data show that the costs and expected costs for each patient in months of July, August, and September. For example, in month of July, the first patient have costs of $391. But the expected cost was $294. So this patient cost more than expected.

Always start the analysis with checking assumptions. We are examining costs, which is typically measured on an interval scale. So check, this assumption was met.

Observations are independent from each other. This assumption is violated if one patient's cost determines another patient's cost. It may be reasonable to assume that each patient costs are independent from each other. I think if you think about it, if you have to pay for somebody else's cost, you'll be quite upset. So it's likely that your costs are independent from other costs. So this assumption is also checked.

The third assumption we need to verify is that there are more than five observations for each time period. In each of the three months, there are more than five observations. So we are OK. This assumption is also checked.

The last assumption we need to verify is that the data are normally distributed. Histogram the observed cost, and do an eyeball test. Is the shape bell-shaped curve with most data in the middle and the little data on the tails?

Here we see a single peak occurring at middle of the data and a most symmetrical distribution of the data around the peak, which reassures us that the data may be normally distributed. For more precise verification of assumption, one can do statistical test for normal distribution. But for all practical situations, an eyeball test will do.

We start the analysis by calculating the average costs for each time period. Here we have plotted the average costs for each time period. A graph helps us see possible relationships. Maybe August was a low-cost month. May wait until you see control limits for what could have been expected. These data don't tell us much until we see them against what could have been expected.

Next, we calculated expected costs within each month. This is the average cost of expected cost for each patient in that time period. Plotting expected cost helps interpret the observed cost but does not settle the question of whether differences are due to chance.

In July and September, the observed costs where above the expected cost. And in August, the opposite. Still we do not know if these deviations are small and due to chance, or something more fundamental has changed in our cost and billing process.

The next step is to calculate the standard deviation of differences of observed and expected costs for each time period. First we calculate the difference of observed and expected costs for all cases in all time periods. Then we calculate the standard deviations of all these differences.

Excel has a formula for calculating standard deviations. The standard deviation for time period j is the standard deviation of differences divided by the square root of the number of observations in time period j. Here are the calculations of differences in each case across three months. After the differences are calculated, then the standard deviation for all differences is calculated to be 63. Finally, this standard deviation is adjusted to estimate the standard deviation for each time period.

Upper control limit for time period j is calculated as expected value for time period j plus t times the standard deviation of differences in time period j. The lower control limit is calculated the same way but now minus t times the standard deviation.

Here are t values for different number of cases. You can draw the control limits at 95% of data within the two limits, or 99% of data within the two limits.

The control limits were 99% of data will by chance fall within the upper and lower control limits for month of July is calculated in the fashion shown here. The expected cost was $335. The t value for 10 cases is 3.2. And the standard deviation for differences in month of July is $20.8.

Here are the calculated control limits for all time periods. We can now examine if the observed average cost is within the control limits.

Notice the way this chart was drawn. Time periods are in the x-axis. Costs are on the y-axis. The observed average cost is shown in the blue line with markers. The upper and lower control limits are shown without markers.

Two points are outside the limits. Each point is just a little bit above the control limit. But nevertheless, it is above the limit. Doesn't matter by how much, as long as it is.

When a point falls outside the control limit, it cannot occur by pure chance. Something else is afoot. Therefore, we could conclude that in July and September, costs were above from what could be expected from patients' severity of illness.

When you distribute the control chart to improvement team members, provide information on how expected cost was calculated. Show that you have thought through assumptions of the control chart, and these assumptions have been met. Summarize the key findings from this chart.

This set of slides have shown us how risk-adjusted Xbar chart compares performance to expectations.