**Transcript for Risk Adjusted P-chart**

FARROKH ALEMI: The purpose of analyzing data and creating control charts is to examine if change we have introduced has truly led to an improvement.

When we analyze data, we move away from blaming individuals and focus on how the system performs.

We move away from case by case reactions and start looking at patterns of care and their outcomes. Control chart discipline our intuitions and help us communicate the system-wide impact of our improvement efforts.

The purpose of p-chart is to detect if the process has improved beyond historical levels. This kind of chart assumes that we serve same type of patients as we have historically done so. And any improvements we see are due to our intervention and not due to underlying change in the nature of the patients.

But the purpose of risk adjusted p-chart is different. We now want to detect if the process has improved beyond what can be expected from patient conditions. We no longer are comparing ourselves to historical patterns. If types of patients have change, this is OK, as risk adjusted control chart takes into account the risk associated with each type of patients. Risk-adjusted control charts compare the outcomes to what should have been expected given the patient's conditions.

For risk-adjusted control charts, we need two types of data. First, we need outcome data over time. This is needed in any control chart, including the standard p-chart. Second, we also need data on patients' risks.

Risk data describe the expected outcome for the patient's condition. The expected outcomes can be measured in different ways.

A severity index can be used to predict patient outcomes. The literature is full of measures of severity or risk of patients.

Clinicians consensus regarding expected outcomes can be used. We can just ask the clinician to tell us what the expected outcome is.

Or we can have the patients rate what outcomes they expect.

In collecting risk and outcome data, keep in mind that the purpose is to improve, not to get so lost in measurement and to lose sight of the improvement goal. We should not spend so much time on data collection that leaves no time for improvement. Keep the big picture in mind. And do not get lost in the minutiae of data collection.

I will show you how to construct a risk-adjusted p-chart by walking you through analysis of this data. On the top two rows are observed mortality during various time periods. In the first time period, 2 out of the 8 cases died. In the second time period, 3 out of the 9 cases died, and so on.

For each case, we will also show expected mortality risk. These data could come from different sources. I particularly like to use the multi-morbidity index to predict the expected prognosis of the patients. For example, we see that the case 8 in time period 1 had 4% chance of dying.

We begin the analysis by checking assumptions.

We are examining discrete events that either happen or do not happen. We want mutually exclusive and exhaustive events. In this case, we are dealing with mortality, which is in fact exhaustive. You are either dead or alive. It is also mutually exclusive. You cannot be both dead and alive.

Another assumption is that the event is not rare, meaning the probability of it occurring exceeds 5% for each time period. The smallest probability of mortality occurs in time period 3 where 1 out of 3 patients die. This is 14% mortality rate. So we meet this assumption too.

We also assume that observed events are independent of each other, that mortality of one patient is not related to the mortality of another. For example, we are assuming that we are not dealing with mortality from an infectious disease.

Finally, we are assuming that the probability of the event does change over time. Mortality depends on patient conditions. And each patient presents with different conditions. As different types of patients present, they will have different rates of mortality. A p-chart assumes that these rates do not change. In contrast, a risk-adjusted p-chart makes the opposite assumption that the rates do in fact change and depend on the patient conditions.

In Step 2, we calculate observed rates of mortality for each time period. This is done by dividing the observed count of mortality with the number of cases in that time period.

Here, I am showing the observed mortality rates for each time period. You cannot see much of the pattern in the data until you plot the rates. Let us take a look.

Time Period 7 and 3 seem different. But don't rush to judgment. Wait until you see control limits of what could have been expected.

In Step 3, we calculate the expected rates for each time period. This is the rate we would have expected to have based on the risk of our patients. It is calculated as the average of the risk faced by all patients during any particular time period. The formula says, the expected value for time period i is this some of the risk faced by patients divided by the total number of the patients in that time period.

For example, for the time period we have, for the time period 1, we have 8 patients at risk ranging from low a 4% chance of mortality to a high of 88% chance. The expected value for the time period 1 is calculated as the sum of the risk of each patient divided by 8.

Here, we see both the observed and the expected mortality rates again. It is hard to compare these numbers until we plot them.

Look at this. We see that in many time periods, the expected and observed mortality rates are close. Time period 3, 5, and 8 seem to have large differences between expected and observed rates. But are these differences large enough to not be due to random chance? Plotting expected mortality helps interpret the observed rates, but does not settle the question of whether differences are due to chance.

In Step 4, we calculate expected deviations. This gives us a sense of how much variation there on the mean can be expected due to chance events.

Expected deviations is calculated by taking the average of the product of the square root of each patient's risk times 1 minus the patient's risk. This formula says in words that deviation at time period i is calculated by first multiplying the risk of each patient by 1 minus the risk of that patient, then summing these products and taking the square root of it, and finally, dividing the square root by number of patients in the time period.

Let us look at these calculations for time period 1. We start by multiplying patient risk in the first time period by 1 minus the risk. In this time period, the first patient has 18% chance of mortality. Multiplying 18% by 1 minus 18% gets us 15%.

We do this for all 8 patients. We sum the products. Take the square root of the sum. Then divide it by number of cases to get 0.134 for estimate of deviation.

Here's the expected deviations calculated for all time periods.

In Step 5, we calculate the control limits. These limits tell us that the range in which data may fall by chance. Upper control limit is calculated as expected value for the time period plus t times the deviation for the time period. Similarly, lower control limit is calculated as expected value for the time period minus t times the deviation.

In this calculation, t is a constant established from t distribution tables found online. It is a concept that is based on degrees of freedom available. Degrees of freedom is calculated as 1 minus number of observations in the time period.

Here is sample calculations for the first time period. 0.28 is the expected value. And 0.13 is the deviation. There are eight observations. So seven degrees of freedom. And the t value is 2.37. Notice, the lower control limit is calculated to be a negative number, which is not possible. So it is reset to 0.

This table shows the calculated lower and upper control limits. This is a control chart drawn from the data we had calculated. The x-axis shows the time periods, here, going from first to eight time period. y-axis shows the probability of the event. The y-axis shows the mortality rate.

The limits are shown as red lines without markers. Here, lower and upper control limits are drawn. Observations are shown as a line with markers to attract attention to each time period.

The points that fall outside the limits are significant, non-chance deviation from the expected values. These are time periods that we perform differently than expected. Control charts tell how we have changed over time.

In Step 6, we interpret the findings from control charts.

There are no points above upper control limit. We did not get worse over time. We didn't have an increase in mortality rates.

There is one point below the lower control limit. In time period 3, mortality is lower than what can be expected from patients' conditions.

Why is that? We don't know. But we should explore why in this time period we did better than expected.

All other time periods are within expectations, even time period 7 with its high mortality rate is within the expectations.

In this last step, the control charts and the interpretation is distributed widely so various people in the organization become aware of the unit's performance. It's important to send the chart to all members of the improvement team and let the data do the talking.

When you distribute the control chart, include something on how the severity of the patients was measured. You might describe how expected mortality was anticipated.

Discuss why you think assumptions were met.

Show the chart and discuss why the chart looks like it does.

List the major findings and the interpretation of the chart.

This brief lecture focused on risk-adjusted p-charts. Risk-adjusted p-charts show how observed rates differ from expectations.