Index

Page references in **bold** indicate tables and those in *italics* indicate figures.

acute myocardial infarction (AMI)  
conceptual clinical flow diagram 200  
patients treated for AMI at 10 hospitals 207  
study of the 30-day mortality of patients suffering from 139–141  
adjustment, experimental 164–166  
anaesthetic processes  
monitoring safety and quality of 63–66  
artificial intelligence 146, 147  
assay quality monitoring 96–98  
asthma patient, PEFR values 60–62, 205  
audit standards 198, 199  
autocorrelated data, control charts for 101–106  
autocorrelation 93–95  
impact of autocorrelation magnitudes on type-1 and type-2 error rates 101–103  
autocorrelation function (ACF) 96, 98, 99  
autocovariance 93–95  
average run length (ARL) 26–27, 78, 79  
binary data, logistic regression on 134–141  
binary measure of quality 188–190  
binary outcome measure 158  
binary variables 114  
binomial distribution 230–232  
blood culture contamination study 66, 67  
blood pressure, variability of measurements 48, 49  
c charts 42–45  
showing number of MRSA infections at a tertiary referral centre 45  
calibration 143  
case-mix adjustment 190, 191  
categorical data 114  
central limit theorem 83, 238, 239  
change, approaches to 5  
checklists 27, 28  
clinical performance 3  
clinical procedures, evaluation of 185  
clinical process measure 2  
clinical processes  
assessing the quality of 195–214  
benchmarking of processes in statistical control 201–210  
changing a process in statistical control guided by samples 31–33  
changing a process that is not in statistical control 33–35
clinical processes (continued)

designing a data system 199–201
development of conceptual model of selected 199, 200
inappropriate changes of 30–35
input/output of 29
not in statistical control in the same state 210–212
Clostridium difficile infections 57–59
X-EWMA chart showing number of days between 89, 90
collinearity 142
common metrics 197
complete discrimination 145
conceptual model, development of 199, 200
certainty interval 217, 244–247
calculating 245–246
of the mean value 246
using to test a hypothesis 249, 250
conforming products 38
continuous data, control charts for 46–62
continuous measure of quality 186, 187
continuous outcome measures 115
continuous probability distributions 226, 234–242
continuous quality improvement (CQI) 166, 178
control charts with adjusted control limits 104–106
analysing the properties of 24–27
for autocorrelated data 101–106
clinical applications 28–30
construction of 14, 15
for continuous data 46–62
design of 22–24
for discrete data 38–45
individual observations 56–62
p charts 38–42, 62–68
performance of traditional 101–103
risk-adjusted 151–161
sample size 23
for sample size larger than 1 46–55
samples and 12–16
sampling frequency 24
statistical control 12
statistical foundation of 11–16
time-weighted 78–91
use of 16–21
for variable sample size 62–76
control limits 22, 23, 156
correlation coefficient, between two random variables 94
count outcome 160
cross validation 146
cumulative risk-adjusted mortality chart (CRAM) 153
cumulative sum (CUSUM) 188
of deviations between observed binary outcome and expected probability of failure of surgical procedures 189
of deviations between observed outcome and expected probability of failure in 20 consecutive surgical procedures 188
cumulative sum (CUSUM) charts 79, 80–86
advantages and disadvantages 83
risk-adjusted 156, 157
risk-adjusted sample statistic and control limits 152
standardised 84
cumulative sum (CUSUM) residual charts 104
data 218–223
categorical 114
distribution of 219–221
location of 222
outliers 218, 219
prerequisite for combining data for multiple purposes 197, 198
of a random sample, using the 243–250
single-point data collection at point of entry 197
spread of 222, 223
data elements, determination based on report list 201
data patterns 25, 26, 51
data processing, requirements 196–201
data system, functional steps in designing 199–201
dataset, inspection for outliers 218, 219
death rates 5
of coronary artery bypass graft operations 33, 34
in a reference group of patients 151
of two patient groups comparing a new surgical procedure and one currently used 193, 194
dependent variables 113, 114
direct standardisation 172
discrete data, control charts for 38–45
discrete probability distributions 226
  examples of 229–233
  variance of 228
discrimination 144–146
  Dixon's test 219
documentation, selection of variables for inclusion in model 146, 147
drug treatment, simulation where dose of drug is adjusted 31
emergency departments, monitoring of patient satisfaction 53–55
emergency readmission rates, following discharge from National Health Service acute trusts 212–214
  estimates 229, 243
EWMA stationary (EWMAST) chart 105
experimental adjustment 164–166
  exponentially weighted moving average (EWMA) charts 58, 79, 80, 86–90
  exponentially weighted moving average (EWMA) residual charts 105
  exponentially weighted moving average (EWMA) statistic 86
first order autoregressive (AR(1)) processes 96
  funnel plots 208, 209
  Gaussian distribution 234–242
    cumulated distribution 236, 237
    testing if a distribution is Gaussian 239
  goodness-of-fit measures 142–146
  hypothesis
    testing a 247–249
    using a confidence interval to test a 249, 250
  in-control average run length (ARL) 26, 27
  independence of measurements, tests of 96–100
  independent variables 113, 114
  indirect standardisation 172
  individual observations 56–62
    X chart 56, 57
  infections, monitoring frequency of 57–59
  information systems 195
    guiding principles for development of 196–199
healthcare providers
  benchmarking of several 207–210
  benchmarking of single 202–207
  characterising the process 203, 204
  defining the quality requirements 202, 203
  relating process to quality requirements 204–207
  risk-adjusted comparison of 164–181
healthcare system, hierarchy of 116
  hierarchical linear regression 127–133
    single level model with fixed provider effect 129
    single level model without provider effect 128, 129
  hierarchical logistic regression model 138–141
    single level model including fixed provider effect 138, 139
    single level model without provider representation 138
  hierarchical models
    clustering of observations 131, 132
    differences between providers 131
    distinctive features of 130, 131
    shrinkage of estimates of provider outcomes 131
  hospital report cards, impact of choice of benchmark 140, 141
  hospitals
    estimates of coefficients of hospital characteristics from a hierarchical regression analysis of healthcare provider, hospital characteristics and patient characteristics 140
    ranked according to appropriateness of treatment 207
  in-control average run length (ARL) 26, 27
  independence of measurements, tests of 96–100
  independent variables 113, 114
  indirect standardisation 172
  individual observations 56–62
    X chart 56, 57
  infections, monitoring frequency of 57–59
  information systems 195
    guiding principles for development of 196–199
institutions, factors that may influence learning curves at 192 interactions 126, 127 in logistic regression 138 tests for 142 interdisciplinary rounds 165, 166 knee replacement see total knee replacement (TKR)

laparoscopic fundoplication operations operating time 186, 187 probability of occurrence of complication during 190 league tables 208

learning curves 185–194 assessing multiple 191, 192 assessing single 186–191 factors affecting 192 and randomised clinical trials 193–194 linear regression of the logarithm of sequence # of operation on log (operation time/hour) 119, 120 and power law regression of operation sequence # on duration of operation 117 single level 117–124

log-linear curve 187 logarithmic curve 187 logistic regression on binary data 134–141 lower control limit (LCL) 16 lower specification limit (LSL) 203

management data 3 mean, continuous change in the same direction 52 mean value, of probability distribution 227, 228 medical complications, number occurring in patients during and immediately after surgical procedures 233 Methicillin resistant Staphylococcus aureus (MRSA) infections, detection of occurrence of 30, 43–45 mixed models see hierarchical models mortality rates see death rates

multidisciplinary rounds 165, 166 multinomial variables 114 multiple learning curves, assessing 191, 192 multiple linear regressions 120 multiple significance testing 214 nonconforming products 38 nonpharmacological procedures, functions used to predict quality of 187 observational data, statistical risk adjustment of 166–173 open-heart surgery, reduction in transport time from theatre to intensive care department 34, 35 out-of-control average run length (ARL) 26, 27 outcome, classes of 197 outcome data 3 outcome measures 115 outliers 218, 219

overdispersion 212–214

p charts 38–42, 62–68 risk-adjusted 152, 153 parameters 228, 229 Pareto charts 27, 28 Parsonnet risk score, in 11 patients prior to cardiac surgery 149, 150 patient records, confidentiality of 198 patient waiting times, study of 18–21 patients factors that may influence learning curves 192 Pareto chart showing occurrence of postoperative medical complications 28 Parsonnet risk score for patients prior to cardiac surgery 149–151 randomisation to healthcare units 165 simulation of experiences of 2000 patients admitted to two hospitals for major surgery 174–177 study of the 30-day mortality of patients suffering from AMI 139–141 treated for AMI at 10 hospitals 207
peak expiratory flow rate (PEFR) measurements 60–62
performance, of traditional control charts 101–103
performance data, adverse effects of publicising 179
performance levels improvement through change 4–6
improvement through selection 4
physicians comparing physicians treating patients within a specified centre 127, 128, 132, 133
factors that may influence learning curves 192
Poisson distribution 42, 232, 233
power law 187
power law regression, on duration of operation 117
prediction error 125
probability distributions 223–242
continuous 226, 234–242
discrete 226, 229–233
mean value of 227, 228
parameters 228, 229
standard deviation of 227, 228
testing if a distribution is Gaussian 239
probability ratio, calculation of 158
probability ratio charts, risk-adjusted 154–161
process data 2
process residual charts 104
process standard deviation estimator, effect of choice on behaviour of 107, 108
process variables 11
propensity score methodology 167, 168, 170
public report cards 178, 179
quality binary measure of 188–190
of clinical processes, assessing 195–214
quality of healthcare definition 1, 2
measures and indicators of 2, 3
quality indicators 3
functions of 3–6
quality measures 3
functions of 3–6
random samples 229
random samples with replacement 225
random sampling, example of 216–218
random variables 11
correlation coefficient 94
covariance between 93
non-stationary 92
stationary 92
randomised clinical trials 165
learning curves and 193, 194
rational samples 24
redundant variables 123, 124
regression on continuous outcome measures 116–133
regression models 116
assessing the quality of 141–147
collinearity 142
conformity with linear gradients for continuous variables 142
events per predictor variable 142
goodness-of-fit measures 142–146
tests for interactions 142
reporting systems, testing 201
reports, generation of list of 200, 201
request forms see test request forms
residual charts 104
result data 3
risk adjusting observational data, perils of 173–178
risk adjustment 149–151
tools for 113–148
risk factor balanced groups, identification of 167–171
risk factor(s), modelling the relation between outcome and 171–173
risk of infection 57
risk-adjusted comparison of healthcare providers 164–181
risk-adjusted control charts 151–161
risk-adjusted CUSUM charts 157
risk-adjusted p charts 152, 153
risk-adjusted probability ratio charts 154–161
risk-adjusted sequential probability ratio test (SPRT) calculation of 155
calculation using a sequence of 9 patients 159, 160
risk-adjusted set charts 161, 162
run down 100
run up 100
runs 25, 100
runs test of randomness 100
S charts 46, 70–76
factors used for 17
for unequal sample size 251–253
sample mean values on $\overline{X}$ chart, 
distribution change when mean of 
process variable changes 50, 51
sample size 23
$S$ chart for unequal 76, 251–253
$X$ bar chart for unequal 76, 
251–253
sample variables 11, 12
samples 29, 30
and control charts 12–16
control charts for variable sample 
size 62–76
random 229
sampling frequency 24
sequential probability ratio test 
(SPRT) 156
calculation using a sequence of 15 
patients 154, 155
sequential probability ratio test 
(SPRT) charts 156
resetting 157
risk-adjusted sample statistic and 
control limits 152
set charts, risk-adjusted 161, 162
Shapiro–Wilks W test 239
Shewhart control charts 11, 
37–77
definition 37
shortcomings of 78–80
simulation experiments, patients 
admitted to two hospitals for major 
surgery 174–177
single level linear regression 117–124
single level logistic regression models 
134–137
including fixed provider effect 138, 139
without provider representation 138
single-point data collection at point of 
entry 197
sinusitis episodes, study of 69, 70, 71
special cause variation example 
of procedure for tracking 21
standard deviation, of probability 
distributions 227, 228
standardised CUSUM charts 84
stationary process 93
stationary time series models 95, 96
statistical concepts, basic 216–250
statistical control 12
statistical foundation of control charts 
11–16
statistical models 115, 116
statistical process control, theory of 
11–36
statistical risk adjustment, of 
observational data 166–173
statistical significance 146
stratification 167
structural data 2
surgeons, effect of training surgeons on 
in-hospital coronary artery bypass 
graft (CABG) surgery 
mortality and morbidity 168–170
surgical procedures
linear regression of sequence # of 
operation on operation time/hour 
118
relationship between skills of 
operator and experience 
117–119
systematic data patterns 25, 26
Tchebichev’s inequality 23
test request forms 39–42
test samples 216
tests of independence of measurements 
96–100
tool of statistical process control 
11–36
throughput process measures 3
time series, white noise 96
time series analysis 93–96
time-weighted control charts 
78–91
tools for risk adjustment 113–148
total knee replacement (TKR)
computer tomography-based 
navigation system 74–76
CUSUM chart of values of (angle 
of femuro-tibial axis)/degree 
measured in patients following 
85
examination of alignment as 
outcome of 74–75, 84–86, 206
type-1 error 22
type-2 error 22
$u$ charts 68–70
depicting number of exceptions 
from a sinusitis care pathway 
70, 72
unbiased estimators 229
unexplained variation 125, 126, 137, 138
upper control limit (UCL) 16
upper specification limit (USL) 202, 203
validity 146
value patterns, control chart 52
variable life adjusted display (VLAD) charts 153, 154
risk-adjusted sample statistic and control limits 152
variables 113–115
  mathematical types of 114
  outcome measures 115
variation, unexplained 125, 126, 137, 138

waiting times
  study of 18–21
Wald’s sequential test 81
warning limits 25
white noise 96

X charts 56, 57, 58, 79, 80, 161
  measurements of PEFR in a patient suffering from asthma 60, 61, 62
\bar{X} charts 11, 19, 22, 37, 46, 70–76, 104
  control limits 16–17, 73
  factors used for 17
  interpretation of 49–55
  for unequal sample size 70–73, 251–253
X residual charts 104