

QUALITY IMPROVEMENT REPORT

Reducing *Clostridium difficile* infection in acute care by using an improvement collaborativeMaxine Power,¹ Neil Wigglesworth,² Emma Donaldson,³ Paul Chadwick,³ Stephen Gillibrand,³ Donald Goldmann^{4,5}¹Department of Health, London SE1 6LH²NHS East Lancashire, Nelson BB9 8AS³Salford Royal NHS Foundation Trust, Salford M6 8HD⁴Harvard School of Public Health, 677 Huntington Avenue, Boston, MA 02115, USA⁵Institute for Healthcare Improvement, 20 University Road, Cambridge, MA 02138Correspondence to: M Power maxine.power@dh.gsi.gov.ukCite this as: *BMJ* 2010;**341**:c3359
doi: 10.1136/bmj.c3359**Abstract****Problem** In 2006, despite a focus on infection control, Salford Royal had the fourth highest rate of *Clostridium difficile* infection in north west England.**Design** Interrupted time series in five collaborative wards (intervention group) and 35 non-collaborative wards (control group).**Setting** University teaching hospital with 850 acute beds.**Key measures for improvement** Number of cases of *C difficile* infection per 1000 occupied bed days.**Strategies for change** In February 2007, a newly formed antimicrobial team led the implementation of revised guidelines in all wards and departments. From March to December 2007, five wards participated in an improvement collaborative. Since December 2007, the changes from the collaborative have been collated and implemented throughout the organisation.**Effects of change** At baseline the non-collaborative wards had 1.15 (95% CI 1.03 to 1.29) cases per 1000 occupied bed days. In August 2007 cases reduced 56% from baseline (0.51, 0.44 to 0.60), which has been maintained since that time. In the collaborative wards, there were 2.60 (2.11 to 3.17) cases per 1000 occupied bed days at baseline. A shift occurred in April 2007 representing a reduction of 73% (0.69, 0.50 to 0.91) from baseline, which has been maintained.**Lessons learnt** Careful use of antimicrobial drugs is important in reducing the number of cases of *C difficile* infection. A collaborative learning model can enable teams to test and implement changes that can accelerate, amplify, and sustain control of *C difficile*.**Outline of problem**Salford Royal NHS Foundation Trust, a university teaching hospital in the north west of England with 850 beds, provides care for about 320 000 inpatients per year. In 2006, Salford Royal had 350 cases of *C difficile* infection in patients aged over 65, the fourth highest rate of infection in north west England.¹ In spite of system-wide changes in infection control, infections rose, peaking at 115 cases during the first quarter of 2007.We describe the effect of three measures: system-wide changes to guidelines and practices for using antimicrobial drugs; an improvement collaborative to reduce the incidence of *C difficile* infection by 50% within one year; and the impact of spreading successful improvements from the collaborative throughout the hospital.**Design**

We used an interrupted time series design in which two groups of participants were observed repeatedly before, during, and after the intervention. Data were collected from five collaborative wards (intervention group) and 35 non-collaborative wards (control group).

Context

During the six months that predated the collaborative, changes were made to infection control throughout the hospital. These included the introduction of a rapid response cleaning team, a deep clean programme, and a focus on hand hygiene and uniform protocols. The only system-wide change that coincided with the study period was the revision of antimicrobial policies and practice.

Selection of participantsWe identified five wards that had a high incidence of *C difficile* infection to take part in the improvement collaborative.**The collaborative model**We ran a Breakthrough Series Collaborative—a short term learning system for teams to work together to deliver improvements.² Teams worked together over a nine month period (mid-March to mid-December 2007). They attended learning sessions, which provided instruction in the theory and practice of improvement, participated in action periods, in which they tested changes, and had ward visits from members of the hospital's executive.**Scale-up and spread of changes**

In December 2007, we scaled up activity across the organisation. We encouraged all wards to implement the successful changes developed by the pilot teams (box).

Key measures for improvementThe primary outcome was the reduction in *C difficile* infection on the five collaborative (intervention) wards between March 2007 and December 2007, measured as cases of *C difficile* infection per 1000 occupied bed days. A secondary outcome was the impact of revised antimicrobial practices (from February 2007) and scale-up (from December 2007) on the whole hospital (non-collaborative (control) wards) from December 2007 to December 2008.

Box 1 | Changes introduced to all wards in February 2007**Antimicrobials**

- An antimicrobial management team comprising a senior pharmacist and a consultant microbiologist reviewed patients receiving antimicrobials and advised medical teams about best practice for their use
- Antimicrobial guidelines were amended to restrict the use of cephalosporins and quinolones in the first line treatment of pneumonia and urinary tract infection
- Access to antimicrobials was restricted by removing third generation cephalosporins and oral quinolones from ward stocks
- Antimicrobial dispensing (including cephalosporins and carbapenems) was restricted to prescriptions issued by consultant grade doctors or junior doctors and specialist registrars who had sought approval from microbiology
- Policy was developed to assure the appropriate use of antimicrobials in surgical prophylaxis

Identification and containment

- A questionnaire was developed covering key issues related to *C difficile* infection and repeatedly administered to all nursing, support, domestic, and clerical staff after training until scores 90% or greater were achieved
- All staff were given focused education targeting knowledge gaps from the questionnaire
- Local protocols were developed to clarify the responsibility of ward teams at the point of suspected symptoms
- On admission, all patients were asked to report symptoms to their named nurse
- Infection control passports were introduced to provide details of patients' requirements on transfer to other units, and for cleaning of wheelchairs and trolleys

Habits and patterns

- Strict enforcement of hand hygiene on entry to ward
- Weekly peer audits for compliance with hand hygiene
- Hand washing rounds for patients before meals and snacks were introduced. Doctors' hand hygiene patterns during rounds were studied and improved
- A poster campaign targeted at improving self caring patients' postmicturition hand hygiene was developed
- Single use soap and shower gel sachets replaced all multiple use products

Environment

- Cultural assumptions were challenged—for example, members of the team were asked to assume that key pieces of equipment were “dirty” until proved clean when they moved equipment from stores to wards
- Disposable washbowls were introduced
- Systems were developed for deep cleaning and curtain replacement
- The bed area was cleaned between patients, and bed and other linens were stored centrally
- Five key surfaces received regular decluttering and wipe with chlorine disinfectant: table, locker, bed rails, buzzer, chair

Process of information gathering**Diagnosis of *C difficile* infection**

Tests for *C difficile* toxin were performed routinely when patients presented with loose stools.

Classification of hospital acquired *C difficile* infection

We restricted our analysis to cases classified as hospital acquired infection more than 48 hours after their index admission.³

Data analysis

We constructed statistical process control charts for rate based data, where the numerator was a count of cases of *C difficile* infection and the denominator occupied bed days. We interpreted patterns of variation in data over time. Cases per 1000 occupied bed days were calculated for the baseline and subsequent shifts.

Reduction in *C difficile* infection

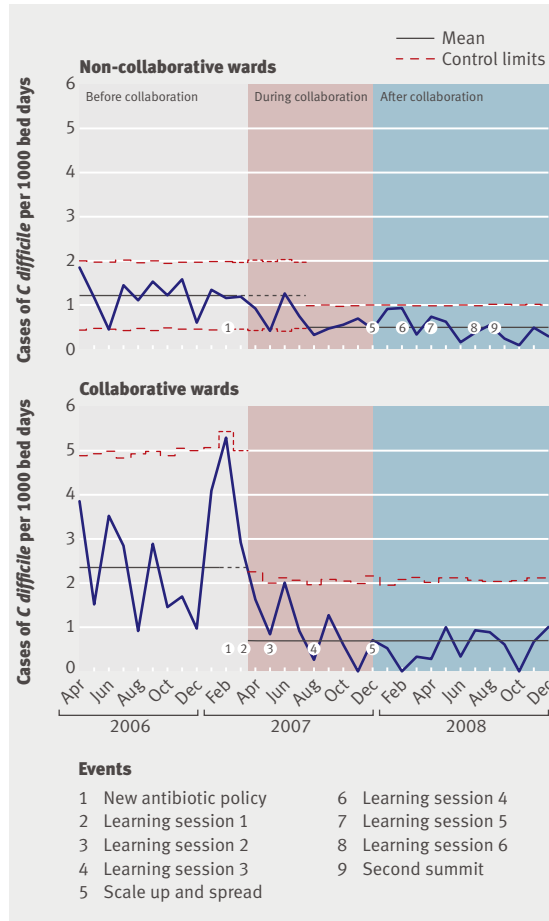
The percentage reduction in *C difficile* infection was calculated by comparing the cases per 1000 occupied bed days during time periods where the data were stable (showed only normal variation) with the baseline (table). Baseline data were collected from April 2006 to the month immediately before the first episode of special cause variation, which occurred in April 2007 for the collaborative wards and August 2007 for the non-collaborative wards (figure).

Strategies for change**Expert group**

In February 2007 we brought together an expert steering group from across specialties. The team examined epidemiological data and decided on a time limited, measurable stretch goal to reduce *C difficile* infection by 50%

Cases of *C difficile* infection per occupied bed days

Period	Cases of <i>C difficile</i> infection	Occupied bed days/1000	Rate per 1000 occupied bed days (95% CI)	% reduction from baseline
Non-collaborative wards:				
Baseline (April 2006 to July 2007)	320	277.655	1.15 (1.03 to 1.29)	
Shift 1 (August 2007 to December 2008)	161	314.276	0.51 (0.44 to 0.60)	55.65
Collaborative wards:				
Baseline (April 2006 to March 2007)	97	37.323	2.60 (2.11 to 3.17)	
Shift 1 (April 2007 to December 2008)	46	67.095	0.69 (0.50 to 0.91)	73.46



Cases of *C difficile* infection in (top) the 35 non-collaborative wards at baseline (April 2006 to June 2007) and up to December 2008 and (bottom) the five collaborative wards at baseline (April 2006 to March 2007) and up to December 2008. Learning sessions 2-4 were attended only by teams from the collaborative wards; sessions 4-6 were hospital-wide

within one year in pilot wards. They identified four key drivers for change: use of antimicrobial drugs; environmental cleaning; early identification and containment of infection; and habits and patterns.

The collaborative

The collaborative included two learning sessions followed by action periods. Teams learnt the model for improvement (including plan-do-study-act cycles), measurement, and the principles of reliability.⁴ Each team selected one of the four key drivers and developed their first test of change. At the second learning session, the teams evaluated their tests. During the next action period, all teams implemented changes and monitored cases. This cycle of learning and testing repeated in each action period—three times in the collaborative wards, then (after scale-up) three times hospital-wide.

Mentoring

A designated sponsor from the hospital’s leadership team supported each of the five project teams. Executive mentoring visits were conducted six times (bimonthly) during each action period (a total of 18 visits).

Changes that resulted in improvement

The top 20 changes developed during the collaborative (see box) were collated into a change package that included step by step guidance on data collection, testing changes, and setting up systems for prospective monitoring.

Effects of change

The non-collaborative wards had 1.15 (95% CI 1.03 to 1.29) cases per 1000 occupied bed days at baseline. One episode of special cause variation (see appendix) occurred in August 2007, six months after the change to antimicrobial prescribing practices, signalled by eight consecutive data points below the baseline mean. This represented a reduction of 56% (to 0.51, 0.44 to 0.60 cases per 1000 occupied bed days) (figure).

The collaborative wards had 2.60 (2.11 to 3.17) cases per 1000 occupied bed days at baseline. One episode of special cause variation occurred in April 2007, two months after the change to antimicrobial prescribing practices and one month after the start of the collaborative. This represented a 73% reduction (to 0.69, 0.50 to 0.91 cases per 1000 occupied bed days), which has been maintained (figure).

Lessons learnt

The primary study question was to determine whether teams participating in the collaborative could reduce *C difficile* infection faster and better than non-collaborative teams. We showed three things:

- Careful use of antimicrobials is key to reducing *C difficile* infection
- Teams participating in an improvement collaborative can deliver more improvement sooner than with careful use of antimicrobials alone
- Sustainable reductions of up to 73% are achievable when infection rates are high.

Discussion

We have shown that many more cases of *C difficile* infection can be avoided than existing reports suggest. Our study shows the importance of careful use of antibiotics on the incidence of *C difficile* infection, and also that simple changes at the frontline can accelerate and amplify reductions.

More complex is the cause and effect relation between the interventions and their impact on outcomes. It would seem that antibiotic stewardship and collaborative participation combined resulted in 73% rate reduction within three months in the five collaborative wards. In the non-collaborative wards, introducing antibiotic stewardship alone had an impact later, but with less effect and without additional benefit from scaling-up of the changes during 2008. It is impossible with this experimental design to apportion the impact of the two interventions.

In 2006, Salford Royal had a higher than average rate of *C difficile* infection, and by the end of the study this had fallen to lower than average for both the health region and England as a whole.

The changes we made (see box) are not prescriptive. It is impossible to determine which of the changes had the greatest impact. Our “package” of interventions may be applicable in other healthcare settings, but other organisations must beware of including changes that may have little effect in a different setting.

Next steps

We believe that ongoing data collection, reporting, and celebration are essential to sustain improvement. Working in partnership with our primary care trust to reduce incidence of *C difficile* infection across the whole health economy is an important next step. We are also working to document the clinical and financial benefits to patients.

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SAFETY ALERTS

Reducing the risk of retained swabs after vaginal birth: summary of a safety report from the National Patient Safety Agency

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This is one of a series of *BMJ* summaries of recommendations to improve patients' safety, based on reports of safety concerns, incident analysis, and other evidence. The articles highlight the risks of incidents that have the potential for serious harm and are not well known, and for which clear preventive actions are available. To report adverse events to the National Patient Safety Agency, go to www.nrls.npsa.nhs.uk/

Why read this summary?

Swabs are used by obstetricians and midwives during vaginal birth and perineal suturing to clean and absorb blood. They can be difficult to identify once soaked in blood and are occasionally left inside the vagina by mistake. This error can cause fever, infection, pain, secondary postpartum haemorrhage, and psychological harm.

Between April 2007 and March 2009, 99 incidents of swabs left in the vagina after birth were reported by healthcare staff in England and Wales. Thirty four of these reports described signs of infection. Litigation claims for the same period showed a further 18 relevant cases.

A typical incident report reads: “Day 8 post NB [Neville Barnes] forceps delivery felt something coming out of vagina. On examination, large swab removed from vagina; swabs taken. Temperature 38°C. Commenced intravenous erythromycin (allergic to penicillin) and metronidazole.”

In perioperative settings, there are established processes for recording and counting swabs. Some of these routine checks could be adapted for use in maternity services, while recognising the range of birth environments.

This summary is based on a new safety report (known as a “rapid response report” or “RRR”) from the National Patient Safety Agency (NPSA) on reducing the risk of retained swabs after vaginal birth and perineal suturing, issued in May 2010. The RRR recommends key actions for staff (NPSA/2010/RRR12; www.nrls.nps.nhs.uk).

Problems identified by the National Patient Safety Agency

The NPSA identified a lack of routine checking for swabs among midwives and obstetricians in some units, with under-recognition of the potential for infection and other complications from swabs retained in the vagina. Reported incidents related to swabs used during birth and perineal repair. Some respondents noted the potential for confusion in situations where both obstetric and midwifery teams were involved—for instance, in obstetric emergencies following failed normal or forceps delivery—with unclear lines of responsibility for swab counts.

What can we do?

In the RRR, the NPSA asked all maternity services to have written procedures in place for swab counts at all births and perineal repairs, and to audit this practice. We recommended a standardised process adapted from general guidance on intrapartum care,¹ existing perioperative practice,² and guidelines from the United States.³

For individual clinicians:

- Always count swabs before and after the procedure. Where possible, do this audibly with a colleague (double counting). Include tampons in the count, which may be used for retraction of tissues during repair of perioperative vaginal tears.
- Record the count (before and after) in the woman's maternity notes or in the electronic maternity record.

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Previous articles in this series

▶ Checking for pregnancy before surgery (BMJ 2010;341:c3402)

▶ Early detection of complications after gastrostomy (BMJ 2010;340:c2160)

▶ Reducing risks of tourniquets left on after finger and toe surgery (BMJ 2010;340:c1981)

▶ Improving the safety of oxygen therapy in hospitals (BMJ 2010;340:c187)

- Where appropriate, record swab counts on a wipe clean surface kept in labour rooms, such as a whiteboard.
- Separate swabs during counting and use a dedicated container for all used swabs. Do not remove used swabs from the area until all counts are reconciled.
- If a woman is transferred to surgery following an emergency during or immediately after a vaginal delivery, document any count in the woman's record and communicate this to the surgical team.
- Use swabs that are detectable on radiography and have safety features, such as tails or tags. Large swabs are more appropriate for this use.
- If a retained swab is suspected, examine the woman, with vaginal bacterial testing and a pelvic radiograph as needed. If the woman is clinically unwell, arrange an obstetric review and start appropriate therapy.

What else do we need to know?

There is little evidence in this area, and most of the evidence relates to swabs and instruments retained after general surgical procedures rather than vaginal births. We do not know how frequently swabs are left in the vagina after birth because incidents are likely to be under-reported to the NPSA. We also do not have robust evidence on the effectiveness of interventions to reduce harm. However, a retrospective study in the US identified several cases of retained swabs after the closure of episiotomy or vaginal tear, and in all cases a count had not been done.⁴ Counting of instruments and swabs is standard perioperative practice and despite some evidence of unreliability of counting,⁵ it is likely that such

simple checks would have prevented most of the cases identified in the US study and reported by staff to the NPSA, whatever the setting.

How will we know when practice has become safer?

Organisations have been given until November 2010 to implement the actions in this RRR and are required to report compliance at that point. The NPSA will continue to monitor incidents reported by staff. This issue would be a good topic for local audit to measure compliance with what should be a routine basic safety process.

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UNCERTAINTIES PAGE**How beneficial is surgery for cervical radiculopathy and myelopathy?**

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This is one of a series of occasional articles that highlight areas of practice where management lacks convincing supporting evidence. The series adviser is David Tovey, editor in chief, the *Cochrane Library*.

Spondylotic degeneration of the cervical spine is associated with ageing and is often asymptomatic,¹ but 10-15% of people with the condition might develop symptoms of compression of the nerve roots (radiculopathy) or spinal cord (myelopathy).² Many factors have been implicated in the tendency to develop radiculopathy or myelopathy, including advanced age, disability at presentation, cord diameter, cord area, altered cord signal on magnetic resonance imaging (T2 and T1 weighted images),³ increased cervical spinal mobility,^{4,5} and the presence of a congenitally narrow spinal canal. These factors might also influence any improvement with an operation, either positively—factors such as increased cervical mobility—or negatively, as a result of advanced age or a congenitally narrow spinal canal.

The natural course of symptomatic cervical degenerative disease is unclear, mainly because no good quality, prospective cohort studies of untreated patients have been conducted. However, the available observational data show that progressive disability is not inevitable, that symptoms might remain static, and patients with apparent disability might improve without surgery.⁶⁻⁹ Patients with radicular symptoms do not necessarily progress to develop overt myelopathy, and in one study at five years, 75% had improved spontaneously.¹⁰ A small randomised controlled trial also found that outcomes after surgery might be similar to those of conservative management.¹¹ Possible complications of surgery include oesophageal perforation, carotid or vertebral artery injury, and permanent damage to nerve roots.¹² Damage to the spinal cord might carry a risk of paraplegia.

RECOMMENDATIONS FOR FURTHER RESEARCH

Radiculopathy

Large scale randomised trial of surgery versus conservative treatment

Population: patients with persistent pain (duration of more than three months)

Intervention: surgery, with or without insertion of arthroplasty

Comparison: surgery (with or without insertion of arthroplasty) plus best medical management versus best medical management. Scope exists for randomised studies to determine what constitutes best medical management (physiotherapy, immobilisation in a collar, anti-inflammatory drugs, or local steroid injection)

Outcome: assessment of time to being pain-free. Physical function and pain score at longer follow-up (at least one year)

Myelopathy

Large scale randomised trial of surgery versus conservative treatment

Population: patients with mild or moderate functional deficit (subtle problems with walking ability and hand dexterity); patients with severe fixed deficit (inability to walk or feed themselves, with or without bowel or bladder dysfunction).

Separation of the relevant radiological subgroups (single or multilevel disease, congenitally narrow canal, hypermobility, presence of altered signal on magnetic resonance imaging)

Intervention: surgery, with or without insertion of arthroplasty

Comparison: surgery (with or without insertion of arthroplasty) plus best medical management versus “delay surgery as long as possible” plus best medical management

Outcome: physical function of arms, legs, and sphincters using validated scales for assessing spondylotic myelopathy, including patient self reported outcomes as well as an independent assessment that is as far as possible blinded to treatment allocation. Follow-up should ideally be long term (up to five years)

What is the evidence of uncertainty?

For our original Cochrane review of the randomised trial evidence on the effect of surgery for cervical radiculopathy or myelopathy we searched BioMed Central, Medline, and Embase up to 1998. To update the review, we searched BioMed Central (the Cochrane Library 2008, issue 2), Medline, Embase, and CINAHL (January 1998 to June 2008).¹³ We contacted the authors of the identified randomised controlled trials for additional published or unpublished data.

Our updated findings

For cervical radiculopathy we found one small prospective randomised controlled trial comparing surgical and conservative treatment in 81 patients.¹¹ At three months, surgery was associated with a greater reduction in pain (reduction of 29% in visual analogue scale) than was physiotherapy (19%) or hard collar immobilisation (4%), but after one year the differences between groups were no longer significant. Similar results were obtained for sensory loss and muscle strength. Surprisingly, no complications were reported, but a large proportion of the surgically treated patients had a second operation between three and 12 months after the first. These results suggest a short term benefit of surgery compared with physiotherapy or immobilisation in terms of pain relief. These data do not suggest that surgery has an effect on the natural course of the disease, and they are supported by prospective non-randomised multicentre investigations.¹⁴ Observational data show that surgery might accelerate clinical deterioration from progression of the pathological process in the treated or adjacent levels of the cervical spine.¹⁵ However, no long term studies have compared cervical arthroplasties with conservative management.

We found one small randomised trial of surgery for mild to moderate cervical spondylotic myelopathy of 68 patients.¹⁶ It found no benefit from surgery compared

with conservative treatment in terms of functional disability at three years. Patients treated with surgery felt individually better, but this was not supported by objective testing of functions, such as walking ability and hand dexterity. No surgical complications were reported, but a large proportion of patients were lost to follow-up. Cervical spondylotic myelopathy is a heterogeneous condition in which some patients might benefit from surgery. This trial was underpowered to detect worthwhile clinical benefits, and the high loss to follow-up made interpretation of results difficult. In addition, non-randomised cohort studies prospectively studying the temporal evolution of myelopathic patients report conflicting results and are unlikely to produce reliable estimates of the balance of risk and benefit from surgery, because they lacked randomised allocation of treatment and independent outcome assessment and depended on outcome measures that were not validated.^{5,7}

Is ongoing research likely to provide relevant evidence?

To our knowledge, no large scale, high quality randomised controlled trials are under way, based on the results of our search strategy for the Cochrane review and personal communications with individuals involved in pertinent research. A current multicentre, international, prospective, non-randomised study of surgery for myelopathy is stratifying patients according to whether their myelopathy is mild, moderate, or severe (M Fehlings, personal communication, 2010). Future research into radiculopathy should focus on the long term effect of surgery—probably comparing surgery that uses evolving techniques (such as various forms of arthroplasties) with “best medical management” (physiotherapy, immobilisation in a collar, anti-inflammatory drugs, or local steroid injection). In relation to myelopathy, patients with mild, moderate, or severe fixed deficit should be included. An effort to separate the relevant radiological subgroups

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- ▶ Does avoidance of peanuts in early life reduce the risk of peanut allergy? (*BMJ* 2010;340:c424)
- ▶ Should we use bath emollients for atopic eczema? (*BMJ* 2009;339:b4273)
- ▶ Should more patients with acute ischaemic stroke receive thrombolytic treatment? (*BMJ* 2009;339:b4584)
- ▶ Is combining or alternating antipyretic therapy more beneficial than monotherapy for febrile children? (*BMJ* 2009;339:b3540)

(single or multilevel disease, congenitally narrow canal, hypermobility, or presence of an altered signal on magnetic resonance imaging) will be advantageous.

What should we do in the light of the uncertainty?

Patients with persistent radiculopathy who are unresponsive to physiotherapy or immobilisation need to know that an early operation might improve their pain faster than conservative treatment, although their symptoms will probably subside eventually without an operation. This is relevant to patients who are worried about the potential complications of surgery. We need additional randomised evidence to provide more precise guidance on the long term effectiveness of surgery, especially with patients who have myelopathic features who might be at risk of progressive disability. Until then, people found incidentally to have asymptomatic spondylosis or who have only mild symptoms can be treated conservatively. For patients with cervical spondylotic cord compression and a progressive neurological deficit, consider offering surgery. The treatment of patients with a major functional deficit could be individually tailored according to the surgeon's expertise and the patient's wishes.

This paper is based on a Cochrane review published in the Cochrane Library 2010, Issue 1 (see www.thecochranelibrary.com for information). Cochrane reviews are regularly updated as new evidence emerges and in response to feedback, and the Cochrane Library should be consulted for the most recent version of the review.

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ANSWERS TO ENDGAMES, p 207. For long answers go to the Education channel on bmj.com

ON EXAMINATION QUIZ

Asthma

Answers A, B, C, and D are correct; answer E is incorrect.

STATISTICAL QUESTION

The log rank test

Answers a and c are true; b and d are false.

PICTURE QUIZ

Black legs

- 1 The bilateral skin lesions on the legs are most likely caused by pellagra.
- 2 The symptom is confabulation.
- 3 T1 weighted images show enlargement of the third ventricle and atrophy of the mammillary bodies of the hypothalamus; this is indicative of Korsakoff's syndrome.
- 4 The patient needs both physical management and psychological care. He should be given oral or intravenous niacin for the pellagra and thiamine for Korsakoff's syndrome in combination with an alimentary diet. He should also be provided with a calm environment and sedative tranquillisers or hypnotics, to prevent mental disturbances including insomnia, anxiety, irritability, aggression, or violence.