NICE National Institute for Health and Care Excellence

NICE guidance

The MAGEC system for spinal lengthening in children with scoliosis

Medical technology guidance

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Contents

1 Recommendations

NICE medical technologies guidance addresses specific technologies notified to NICE by sponsors. The 'case for adoption' is based on the claimed advantages of introducing the specific technology compared with current management of the condition. This case is reviewed against the evidence submitted and expert advice. If the case for adopting the technology is supported, then the technology has been found to offer advantages to patients and the NHS. The specific recommendations on individual technologies are not intended to limit use of other relevant technologies which may offer similar advantages.

1.1 The case for adopting the MAGEC system for spinal lengthening in children with scoliosis is supported by the evidence. Using the MAGEC system would avoid repeated surgical procedures for growth rod lengthening. This could reduce complications and have other physical and psychological benefits for affected children and their families.

1.2 The MAGEC system should be considered for use in children with scoliosis aged 2 years and over who need surgery to correct their spinal curvature, for example when conservative methods such as bracing or casting have failed.

1.3 Findings from cost modelling estimate that using the MAGEC system is cost saving compared with conventional growth rods from about 3 years after first insertion. The estimated cost saving per child after 6 years is around £12,077. The cost savings remained robust in sensitivity analyses. Further savings could be made by avoiding the need for spinal cord monitoring, which is sometimes used during conventional growth rod lengthening but is not needed when lengthening the MAGEC growth rods.

2 The technology

Description of the technology

2.1 The MAGEC spinal bracing and distraction system (Ellipse Technologies Inc.) is used in children aged 2 years or over to brace the spine during growth and minimise the progression of scoliosis. The technology is intended to be used in place of current growth rod systems that need repeated invasive surgical procedures. The MAGEC growth rods are usually removed and replaced by a spinal fixation system to fuse the spine when skeletal maturity is reached.

2.2 The MAGEC system comprises 1 or 2 sterile titanium implantable growth rods and an external remote control for non-invasive lengthening. The diameter of the rods used depends on the child's body weight (4.5 mm for children weighing up to 27 kg, 5.5 mm for children weighing up to 36 kg). The choice of whether to insert 1 or 2 rods is made by the surgeon and depends mainly on the child's size. A portion of each MAGEC rod contains a proprietary distraction element, the 'actuator', which includes an internal cylindrical rare earth magnet. The system also includes a manual distractor (to check the implant is functional before implantation) and a wand locator (to locate the internal magnet).

2.3 The MAGEC system received a CE mark in 2009 for the growth rods and external remote control. A keeper plate was added to the actuator in 2010 to prevent the internal magnet rotating. If this happened when the rod was placed under large amounts of stress, it could cause the rod to slip with some loss of distraction. Following the examination of rod breakages, the design was further revised in 2012 to strengthen the titanium rods by using continuous wave, rather than pulse, laser welding.

2.4 The MAGEC rods are inserted surgically in the same way as conventional growth rods. Distractions (lengthenings) are carried out typically every 3 months, depending on clinical assessment and the surgeon's judgement as to the optimal length of time between distractions for the individual child. The distractions are performed in an outpatient setting without the need for anaesthesia, sedation or pain relief. The magnet within the actuator is connected to a lead screw and is rotated non-invasively by the external remote control, causing the rod to lengthen and increase the distraction of the spine. The external remote control is portable and uses permanent magnets to rotate

the magnet within the rod. The control's display module gives a real-time indication of the amount of distraction or retraction gained. Verification of the new rod length can be done using X-ray or ultrasound if needed.

2.5 The cost of the MAGEC system stated in the sponsor's submission is £13,500 to £14,000 for a set of dual rods, with an additional £450 to £500 for the hooks and screws (supplied by another company) to attach the rods to the spine. These costs are exclusive of VAT. The external remote control is loaned by the sponsor at no cost, other than that of sending it to the treatment centre.

2.6 The claimed benefits of the MAGEC system in the case for adoption presented by the sponsor are:

- The avoidance of repeated surgical procedures, leading to:
  - A reduction in the incidence of surgical complications, including anaesthetic risk, infections and delayed recovery.
  - A reduction in psychological trauma to the child and family.
  - Improved quality of life because of reduced time away from school (child) and work (parent).
- The avoidance of costs associated with repeated surgical interventions, including theatre time, consumables, in-hospital stay and treatment of complications.
- A reduction in costs to society associated with the parent or carer taking time off work and the child being away from school.

Current management

2.7 In many cases of childhood scoliosis, interventional treatment is not needed because the condition corrects itself as the child grows. For those children needing treatment, there are 4 main types, namely casting, bracing, insertion of growth rods and spinal fusion. The type of treatment chosen depends on the age and development of the child as well as the type of curvature of the spine. Casting involves use of an external cast, made from a combination of plaster-of-Paris and modern casting material, which is applied to help guide a child's spine into a normal position during growth. The cast is worn permanently by the child and is replaced frequently as the child grows. Bracing involves use of a rigid or

flexible brace. Bracing rarely corrects scoliosis, but can prevent curve progression and allow the spine to grow before a more permanent treatment is offered.

2.8 Around 120 children with scoliosis per year in England need surgical intervention to implant growth rods to correct the curvature of their spine. This type of surgery is performed if the spinal curvature progresses despite bracing and casting. It involves inserting growth rods (single or dual), which are attached to the spine or ribs above and below the curve using hooks and pedicle screws. The rods can be placed around the cervical or thoracic part of the spine, extending down to the ribs, lumbar spine or pelvis. The initial insertion procedure for the MAGEC system is similar to that for conventional growth rods and usually involves staying in hospital for 5–14 days and several weeks away from school and usual daily activities. If a conventional growth rod is used, the child returns about every 6 months to have a surgical procedure for rod lengthening. The procedure involves manually lengthening the growth rods via small incisions in the back under general anaesthesia. This can be done as a day case procedure but may often involve an overnight stay in hospital.

3 Clinical evidence

Summary of clinical evidence

3.1 Full details of all clinical outcomes considered by the Committee are available in the assessment report overview.

3.2 The key clinical outcomes for the MAGEC system presented in the decision problem were:

- the total number of surgical procedures and anaesthetics
- the total number of outpatient attendances and procedures
- recovery time
- total length of stay
- rate of distraction procedure success
- infection rates and other surgical complication rates
- total number of imaging procedures
- quality of life
- device failure
- device and radiation exposure-related adverse events.

3.3 The sponsor addressed 5 of the outcome measures defined in the decision problem, and added additional outcomes including Cobb angle (a measure of spinal curvature based on a spinal radiograph), thoracic and total spine height. Outcomes relating to pulmonary function were also reported. The sponsor stated that these outcomes were reported in clinical studies, whereas several outcomes in the scope, such as quality of life, recovery time and total length of stay were not and could, therefore, not be addressed.

3.4 The sponsor identified 4 published and 6 unpublished studies relevant to the MAGEC system. The sponsor excluded 2 of the unpublished studies because they were records of ongoing clinical trials and had not reported any findings. The remaining 8 papers were included in the sponsor's summary of clinical

evidence (Akbarnia et al. 2012, 2013a, 2013b; Cheung et al. 2012; Dannawi et al. 2013; Ellipse Technologies Inc. 2013; Richards and Nnadi 2013; Yoon et al. 2013). The study by Akbarnia et al. (2012) was excluded from further consideration because it was an animal study. The unpublished study by Richards and Nnadi (2013) was excluded because it was a cost analysis, but this report was included as economic evidence elsewhere in the submission. The studies by Akbarnia et al. (2013b) and Yoon et al. (2013) were excluded from the sponsor's evidence synthesis because they described patients already included in the studies by Ellipse (2013) and Dannawi et al. (2013) respectively. In summary, 6 studies formed the basis of the sponsor's clinical evidence presentation, of which 4 were included in the evidence synthesis. The External Assessment Centre considered that the studies presented by the sponsor were in keeping with the scope and were appropriate for inclusion.

3.5 Akbarnia et al. (2013a) reported preliminary findings from a prospective, observational multicentre study involving 14 children with early-onset scoliosis who received the MAGEC system rods. The mean age of the participating children was 8 years 10 months, with a range of 3–12 years. Single-rod surgery was carried out in 5 children and dual-rod surgery in 9 children. All children were given a brace for 3–6 months after surgery. The mean follow-up time was 10 months and the mean number of distractions per child was 4.9.
The mean pre-operative Cobb angle was 60°. Post-operatively, the mean Cobb angle was 34° initially and 31° at the latest follow-up. Mean pre-operative thoracic spine height was 178 mm, increasing to 198 mm after surgery and 208 mm at the latest follow-up. Mean pre-operative total spine height increased from 292 mm pre-operatively to 322 mm post-operatively and 338 mm at final follow-up. The changes in total spine height were all reported to be statistically significant ($p<0.05$). No significant differences in the Cobb angle correction were found between children receiving single or dual rods. Complications included superficial infection in 1 child with a single rod, a prominent implant in 1 child with dual rods, and partial loss of initial spine height in 3 children with single rods immediately after surgery. Partial loss of distraction (a reduction in rod length) was observed after 11 out of 68 distractions but was subsequently regained.

3.6 Cheung et al. (2012) reported a prospective case series, reviewing outcomes for 2 children with scoliosis receiving MAGEC system rods, followed up for 24 months. A single rod was used for a 5-year-old child and dual

rods for a 12-year-old child. Both children wore a brace for 3 months post-operatively. Distractions were carried out monthly in an outpatient setting, with an average lengthening of 1.5–2 mm. X-rays were used to measure the Cobb angle, spine height and amount of distraction. Pain was assessed using a visual analogue scale to produce a pain score and the children also completed a quality-of-life questionnaire for scoliosis (SRS-30). The child with a single rod had a change in Cobb angle from 74° pre-operatively to 19° immediately post-surgery and 26° after 24 months. In the child with dual rods, the Cobb angle changed from 60° pre-operatively to 31° after surgery and remained at 31° after 24 months. The authors reported the mean change in length of the instrumented segment of the spine after each distraction to be 1.9 mm±0.4 mm. Mean thoracic spine height increased from 199 mm at baseline to 203 mm post-operatively and subsequently to 229 mm after 24 months. Mean total spine height increased from 314 mm at baseline to 331 mm after surgery and 360 mm after 24 months. The authors reported that the mean monthly increases in spine height were greater than those predicted by standard growth charts. The pain score was 0 (no pain) pre-operatively and at each stage of follow-up. Superficial infection occurred in 1 child. Loss of distraction occurred after 1 of 43 procedures. This related to an excess bending moment in the rod causing slippage in the magnetic section, which led the sponsor to make an improvement in the rod's design (described in section 2.3).

3.7 Dannawi et al. (2013) reported a prospective case series involving 34 children with early-onset scoliosis receiving the MAGEC system rods in a UK hospital. Children were included if they had progression of curvature greater than 10° over 6 months and a Cobb angle greater than 40°. The mean age of the children was 8 years, ranging from 5 to 12 years. Mean follow-up time was 15 months, with a minimum of 12 months. Single rods were used for 12 children and dual rods for 22 children. Each child received at least 3 distractions and the mean number of distractions per child was 4.8 (range 3–6). Surgery with conventional growth rods had already been carried out in 2 children before conversion to the MAGEC system rods at their parents' request (to potentially reduce the number of surgical procedures for their children). These children had Cobb angles of 75° and 80° at the time of conversion. Distractions were carried out approximately every 3 months (mean 87 days) in an outpatient setting with the aim of achieving 4.5 mm growth following each distraction. Cobb angle and total spine height were measured pre- and post-operatively. The mean pre-operative Cobb

angle was 69°. This decreased to a mean of 47° post-operatively and to 41° at final reported follow-up. The mean pre-operative total spine height was 304 mm: this increased to 335 mm immediately after surgery and to 348 mm at final review. The differences between Cobb angle measurements pre- and post-operatively and after follow-up in the single (n=12) and dual rod (n=22) groups were found to be statistically significant within each group ($p<0.001$). Similarly, the differences in the mean total spine height pre- and post-operatively and after follow-up in each group were statistically significant ($p<0.001$). Superficial infection occurred in 2 children, and there were 2 rod breakages needing revision. Loss of distraction occurred in 2 children, which was later rectified. This contributed to the subsequent revision of the rod design, as did the study by Cheung et al. (2012).

3.8 The unpublished study by Ellipse (2013) was a retrospective review including 54 children with early-onset spinal deformity associated with thoracic insufficiency (inability of the thorax to support normal respiration or lung growth) receiving MAGEC system rods. Children were included from 15 centres in 8 countries. Of these, 30 children had MAGEC rods inserted as their first (de novo) surgery and 24 had had previous spinal surgery to insert conventional growth rods. The sponsor's submission included a study report describing outcomes for 14 of these children. The sponsor supplied further data on all 54 children but the External Assessment Centre only included data on the 30 de novo patients from the original submission because it considered that revision surgery outcomes may not be directly comparable with those for initial surgery. The mean age of the 30 included children was 7 years, ranging from 2 to 10 years. Out of the 30 children having de novo surgery, 9 received a single rod and 21 received dual rods. Mean follow-up time for the children having de novo surgery was 21 months. At baseline the Cobb angle was measured in 28 children and total spine height was measured in 27 children. Thoracic spine height and space available for lungs (SAL) were also measured and each measurement was repeated post-operatively and at follow-up. The mean Cobb angle changed from 64° at baseline to 35° post-operatively and then to 43° at final follow-up. The mean total spine height was 264 mm pre-operatively, increasing to 308 mm post-operatively and 312 mm at final follow-up. The mean thoracic spine height increased from 164 mm pre-operatively to 192 mm post-operatively and 194 mm at final follow-up. These differences were found to be statistically significant ($p<0.001$). The change in SAL was reported for 5 children who had a

baseline SAL of less than or equal to 90%. For these 5 children, mean SAL increased by 27% after 24 months.

3.9 Akbarnia et al. (2013b) reported on a retrospective matched case series involving children with early-onset scoliosis: 12 treated with the MAGEC system rods and 12 treated with conventional growth rods, in 5 centres worldwide. The 12 children in the MAGEC system group were included in the Ellipse (2013) study and were therefore not included in the sponsor's evidence synthesis. This study is summarised here because it is the only study that compared the MAGEC system against conventional growth rods. The children were matched by disease type, sex (when possible), age, degree of curvature and receipt of single or dual rods. Their mean age was 6.8 years in the MAGEC group and 6.6 years in the conventional growth rod group. The mean follow-up time differed between the 2 groups, being 2.5 years in the MAGEC group and 4.1 years in the conventional growth rod group. In the MAGEC group, the Cobb angle changed from a pre-operative (baseline) mean of 59° to 32° immediately post-operatively and 38° at the latest follow-up. In the conventional growth rod group, the mean Cobb angle changed from 60° at baseline to 31° post-operatively and 41° at the latest follow-up. The mean increase in spine height post-operatively was statistically significantly smaller in the MAGEC group compared with the conventional growth rod group (18 mm compared with 41 mm; p=0.04). The mean change in spine height from baseline to final follow-up between the 2 groups was also statistically significantly smaller in the MAGEC group compared with the conventional growth rod group (38 mm compared with 77 mm respectively; p=0.01). Mean annual total spine growth was less in the MAGEC group (7 mm per year) compared with the conventional growth rod group (11 mm per year), but this difference was not statistically significant. The authors suggested that the initial surgery could have contributed to the difference in increase in total spine height from baseline to final follow-up, which could be a result of differences in surgical technique across the participating sites. Children in the MAGEC group needed 4 revision operations compared with 17 for those in the conventional growth rod group. In the MAGEC group, 14 complications occurred, of which 10 were implant-related; in the conventional growth rod group, 23 complications occurred, of which 15 were implant-related. Children in the MAGEC system group had fewer surgical site infections (1 compared with 3).

3.10 Yoon et al. (2013) reported on a retrospective case series evaluating pulmonary function in 6 children with early-onset scoliosis secondary to neuromuscular disease treated with the MAGEC system in a UK hospital. The mean age at the time of surgery was 7.5 years and mean follow-up was 2.5 years. Pulmonary function tests were carried out before and after the insertion of the MAGEC rods and at each distraction. The authors reported that the severity of lung function deficit for 2 of the children treated meant that they would not have been able to receive conventional growth rods, but no further details of the children's condition were provided. Other outcomes measured were Cobb angle, amount of rod lengthening and total spine height, but these results were included in the study by Dannawi et al. (2013). Dual rods were implanted in 5 of the 6 children. An average of 7 distractions per child was carried out during the study period. Forced vital capacity (FVC) increased from 27% to 41% of predicted value[1] (p=0.028) and forced expiratory volume in 1 second (FEV1) increased from 27% to 45% of predicted value (p=0.027). Coronal and sagittal Cobb angle, thoracic kyphosis and spine height all showed improvement and the authors reported a moderate positive trend between the amount of distraction and the observed improvement in FVC.

3.11 The sponsor carried out meta- and qualitative analyses of the clinical evidence, including 4 studies of the MAGEC system (Akbarnia et al. 2013a; Cheung et al. 2012; Dannawi et al. 2013 and Ellipse 2013) and 1 study (Bess et al. 2010) which evaluated complication rates for 140 children treated with conventional growth rods. The conventional growth rod arm of the study by Akbarnia et al. (2013b) was also included. The outcomes considered in the meta-analysis were Cobb angle, and thoracic and total spine heights. Qualitative analysis was carried out on infection rates, number of operations, distraction rates and device failure.

3.12 In addition to the adverse events reported in the clinical evidence, the sponsor described 12 adverse events in its submission that had been reported to regulatory agencies. These 12 events related to broken or malfunctioning rods and resulted in 4 revision operations. The External Assessment Centre sought clinical expert opinion on the relative safety of the MAGEC system compared with conventional growth rods; the experts did not describe any significant safety concerns.

3.13 The External Assessment Centre carried out revised meta- and quantitative analyses, in order to consider a broader range of evidence on conventional growth rods. The External Assessment Centre carried out a systematic literature review including data from 15 studies on conventional growth rods, along with the conventional growth rod arm of the Akbarnia et al. (2013b) study. The analyses included the same 4 MAGEC system studies used by the sponsor.

3.14 The External Assessment Centre noted several differences between the populations in the MAGEC system studies and the conventional growth rod studies at baseline, including a lower mean Cobb angle (65.7° and 72.4° respectively), a greater mean total spine height (288 mm and 258 mm respectively) and a difference in mean age at the time of rod insertion (8.0 years and 6.4 years respectively). The External Assessment Centre considered that these differences were likely to have influenced the potential change in each outcome over time. For example, greater height at baseline may limit the potential for growth during follow-up. Similarly, a less severe Cobb angle may limit the potential for improvement in Cobb angle measurement. Inclusion criteria in the conventional growth rod studies varied, with some using Cobb angle and others using age or progression of disease. Dual rods were used in approximately 64% of children involved in the study. Mean duration of follow-up was 4.3 years, which is longer than that of any of the MAGEC system studies (mean 2.5 years). However, the External Assessment Centre considered the studies to be sufficiently homogenous in terms of population, intervention, setting, study design and outcomes to be included in a meta-analysis.

3.15 The conventional growth rod studies were considered in 2 groups, depending on the duration of follow-up: less than 38 months or 38 months and over. The period of 38 months was selected after considering the mean and range of follow-up times. The aim was to allow a more direct comparison with the shorter follow-up in the MAGEC system studies. The outcomes considered were Cobb angle, total spine height and infection rate. Heterogeneity was measured for each outcome and results from fixed and random effects models were presented. All 4 MAGEC system studies were included in the meta-analysis for each outcome, but conventional growth rod studies were only included if they provided usable data for the particular outcome. Quantitative analysis was conducted for the number of surgical procedures (per child and per year), rate of distraction and rate of device failure.

3.16 Findings from the External Assessment Centre's revised meta-analysis and quantitative analysis are presented in tables 1 and 2. The mean change in Cobb angle from baseline was 27° for the MAGEC system studies and 32° for the conventional growth rod longer follow-up studies, with low heterogeneity between studies. The External Assessment Centre considered that the figures for these 2 groups were unlikely to be comparable because of the difference in follow-up time. The shorter follow-up study reported a mean change in Cobb angle of 37°, but this showed variation from the other conventional growth rod studies. The MAGEC studies showed a mean change in total spine height of 4.55 cm with very low heterogeneity. Heterogeneity was very high between the conventional growth rod studies, indicating clinical or methodological diversity across the studies and so limiting the usefulness of the results. There were also differences in age range between the studies. The mean change in total spine height was 6.43 cm for the longer follow-up group and 10.76 cm for the shorter follow-up group. The MAGEC studies showed moderate heterogeneity and a mean infection rate per patient of 3–4%. The infection rates in the conventional rod groups varied from 3–17%, but these rates were complicated by limited reporting in the included studies, with uncertainty around the type of infection included.

3.17 Results of the External Assessment Centre's revised quantitative analysis showed that the number of surgical procedures per child was less in the MAGEC system group (1.2) than in both the shorter and longer follow-up conventional growth rod groups (4.3 and 5.8 respectively). Calculated annual procedure rates per child (including initial surgery) were 0.9 for the MAGEC system group and 1.5 and 1.1 for the shorter and longer follow-up conventional growth rod groups respectively. The mean number of distractions per child was higher in the MAGEC system group than in the conventional growth rod groups, at 6.2 compared with 4.2 (shorter follow-up) and 4.6 (longer follow-up). The only type of device failure reported was rod breakage. The mean rates of device failure per child were lower in the MAGEC system group than in either conventional growth rod group (MAGEC 6%, shorter follow-up conventional growth rods 13%, longer follow-up conventional growth rods 31%). The annualised rates were around 4.5% in the MAGEC system and shorter follow-up conventional growth rod groups and 7.2% in the longer follow-up conventional growth rod group. The External Assessment Centre noted that these results may reflect the more frequent use of single rods rather than dual rods in the past, which are known to have a higher risk of failure. It noted that results may also have been

influenced by advances in rod design, mainly relating to the use of stainless steel rods in the past compared with the stronger titanium rods currently used.

Table 1 Results of the External Assessment Centre's revised meta-analysis

	Number of studies included	Heterogeneity I^{2*}	Fixed effects model or single study (mean, lcl–ucl)	Random effects model (mean, lcl–ucl)
Cobb angle (°)				
MAGEC system	4	44.89	27.16 (24.41–29.92)	27.17 (23.12–31.22)
CGR shorter follow-up	1	N/A (1 study)	37.03 (27.26–46.80)	–
CGR longer follow-up	4	34.83	32.14 (28.91–35.36	32.90 (28.61–37.18)
Change in total spine height (cm)				
MAGEC system	4	0	4.55 (3.98–5.11)	4.55 (3.98–5.11)
CGR shorter follow-up	2	92.33	12.29 (11.16–13.43)	10.76 (5.53–15.98)
CGR longer follow-up	3	96.5	4.25 (3.77–4.72)	6.43 (2.70–10.15)
Infection rates (% per patient)				
MAGEC system	4	61.68	0.03 (0.00–0.08)	0.04 (0.00–0.15)
CGR shorter follow-up	2	83.75	0.03 (0.00–0.08)	0.03 (0.00–0.25)
CGR shorter follow-up (Zhao et al. [2012] study only)	1	N/A (1 study)	0.12 (0.03–0.31)	–
CGR longer follow-up	8	57.33	0.14 (0.11–0.16)	0.15 (0.11–0.20)

CGR longer follow-up (without Kabirian [2012a] study)	7	38.74	0.16 (0.13–0.20)	0.17 (0.13–0.21)

*Values for measuring heterogeneity between studies: <50% is low, 50–70% is moderate and >70% is high

CGR, conventional growth rods; lcl, lower confidence interval; ucl, upper confidence interval

Table 2 Results of the External Assessment Centre's revised quantitative analysis

	Number of patients	Total number of outcomes	Mean per patient	Mean per patient per year	Average interval
Surgical procedures					
MAGEC	80	95	1.2	–	–
CGR shorter follow-up	78	336	4.3	–	–
CGR longer follow-up	264	1523	5.8	–	–
Distractions					
MAGEC	80	496	6.2	4.5	2.3
CGR shorter follow-up	30	125	4.2	1.4	8.6
CGR longer follow-up	555	2557	4.6	1.1	9.2
Device failure			**% per patient**		
MAGEC	80	5	6.3%	–	–
CGR shorter follow-up	103	13	12.6%	–	–
CGR longer follow-up	808	254	31.4%	–	–

CGR, conventional growth rods

Committee considerations

3.18 The Committee considered that the clinical evidence was limited because it was restricted to small observational studies, and so was insufficient in quantity or quality to establish clinical superiority of the MAGEC system compared with conventional growth rod systems for lengthening the spine and reducing spinal curvature in children with scoliosis. However, it judged that the evidence provided by the various studies, taken together with clinical expert advice, was sufficient to demonstrate the clinical non-inferiority of the MAGEC system with the conventional growth rod systems.

3.19 The Committee was advised that the population of children with scoliosis is heterogeneous, because scoliosis has multiple causes and children may have different comorbidities and magnitudes of curvature. The Committee considered that this was an important confounding factor in the clinical studies. The Committee also noted that the differences in baseline characteristics such as age, Cobb angle and spine height between the children treated with the MAGEC system and conventional growth rods in the available clinical studies could have affected the results. The Committee was advised that the age at which growth rods are first inserted will affect the growth potential of the child's spine, with younger children having more growth potential than older children.

3.20 The Committee was advised that the MAGEC growth rods are functionally similar to conventional rods and are attached to the spine in the same way. It was also advised by experts that the initial reduction in Cobb angle at the time of insertion of growth rods should be similar for the 2 systems. The Committee noted that the External Assessment Centre's review of the clinical evidence indicated that the device failure rate of the MAGEC system rods was at least equivalent to that of conventional growth rods.

3.21 The Committee was advised that Cobb angle and spine height are often difficult to measure and are subject to variation in interpretation when viewing images of the spine. Nevertheless, experts stated that these measures are currently the most reliable indicators of changes in spinal curvature and growth of the spine for children with scoliosis.

3.22 The Committee judged that, because of the uncertainty around the clinical evidence and the available measures, a system for capturing data on individual cases – such as a register – would be useful to expand the evidence base for the use of growth rods, including the MAGEC system. Experts stated that a British Spine Registry was set up by the British Association of Spinal Surgeons in 2012, and it is hoped that this will include data on children with scoliosis. The Committee thought that this would be very valuable in view of the clinical data uncertainties.

3.23 The Committee considered that the MAGEC system had significant potential to improve quality of life for children needing surgical treatment for scoliosis and for their families or carers. In particular, it noted the benefits associated with avoiding the repeated surgical procedures for lengthening conventional growth rods. These included outcomes such as less pain, less time in hospital and less time away from usual activities, as well as a reduced risk of infection and less scarring. In addition, the Committee noted the potential for less psychological distress, mainly fear and anxiety about the lengthening procedures. The Committee heard patient expert contributions describing the positive attitude of children going to hospital for distraction procedures with the MAGEC system, compared with the distress they experienced when attending for surgical lengthening of conventional growth rods. The Committee was told that grouping outpatient appointments together for children with the MAGEC system rods can not only enhance efficiency (because the external remote control can be used for a number of children in a single clinic), but has the additional benefit of allowing the children to interact, reducing their sense of isolation.

3.24 The Committee recognised that the MAGEC system offers the possibility of more frequent and gradual distraction of the spine than conventional growth rods. The Committee heard clinical expert advice that the optimal frequency of distractions and the amount of lengthening done at each appointment remains uncertain and that practice is evolving: specifically, the frequency of distractions may increase in future. The Committee was clear that any increase in the frequency of distractions would need to take into account the increased radiation exposure from multiple imaging procedures (see section 3.27).

3.25 The Committee noted that the MAGEC system may offer particular advantages for some children who are at high risk from repeated surgical procedures, by

removing the need for those procedures and the associated risk of complications. The Committee was also advised that the MAGEC system may provide an option for children for whom treatment with growth rods would otherwise be considered unsuitable because of the risks from repeated surgical lengthening procedures. This may offer benefits to those children (in terms of their quality of life) and to the healthcare system (in terms of less need for treatment of associated conditions, such as chest infections). However, this group was outside the scope of this evaluation.

3.26 The Committee heard clinical expert advice that the MAGEC system may be unsuitable for use in children with severe kyphotic curves, because a flat section of spine is needed for distraction with the MAGEC system. The Committee considered that the decision to use the MAGEC system or conventional rods would depend on the individual child's condition and the wishes of the child and their family, after careful discussion of the available options.

3.27 The Committee considered the potential impact of additional imaging associated with more frequent distractions. The Committee was advised that X-rays were not always used after each distraction and that ultrasound may be an option for more frequent distractions. The Committee was also advised that the use of magnetic resonance imaging (MRI) is currently contraindicated for children with MAGEC system rods in place, but that research is in progress to determine whether any level of MRI can be carried out safely and effectively in these children. The Committee considered that further evidence should be developed about the relative merits of X-rays, MRI and other imaging techniques such as ultrasound in children being treated with the MAGEC system.

[1] The test result is often shown as a percentage of the 'predicted values' for patients of similar characteristics. A result close to 100% is considered to be normal, although results over 80% are often also considered normal.

4 NHS considerations

System impact

4.1 The sponsor claimed that the MAGEC system reduces the number of surgical procedures needed to treat children with scoliosis compared with conventional growth rods, because rod lengthenings and distractions are carried out non-invasively in an outpatient setting. This reduces resource use such as operating theatre and clinical time, as well as reducing the risk of complications needing hospital treatment, such as side effects from anaesthesia or infection.

Committee considerations

4.2 Having reviewed the clinical evidence and expert advice, the Committee was satisfied that using the MAGEC system could reduce the number of surgical procedures for each child by avoiding the need for operations to lengthen conventional growth rods. This would also reduce associated NHS resource use.

4.3 The Committee was advised that the population of children for whom the MAGEC system would be considered is small, but that the potential for releasing operating theatre and clinical time and shortening hospital stays by avoiding repeated surgical procedures could be substantial. The Committee also noted that resource use for treating complications associated with surgery, such as infection, could be reduced.

4.4 The Committee was advised that MAGEC growth rod lengthenings are often carried out in a single clinic, specially arranged so that a number of children can be treated. This allows more effective use of resources through reduced courier costs for the external remote control.

4.5 The Committee was advised that the MAGEC system may reduce the need for spinal cord monitoring and its associated costs. Spinal cord monitoring is used to assess neurological function during insertion of MAGEC or conventional growth rods, and in some children during conventional growth rod lengthening. However, it is not needed during lengthening of the MAGEC system rods because the child is awake and any changes in function can be observed.

5 Cost considerations

Cost evidence

5.1 The sponsor presented 1 unpublished economic study set in an English hospital as evidence for the evaluation (Richards and Nnadi 2013), which was submitted to the Committee as academic-in-confidence. The External Assessment Centre judged that the study was relevant to the scope of the evaluation and found no additional relevant studies.

5.2 The sponsor submitted a de novo cost analysis comparing the cost consequences of using the MAGEC system with 1 type of conventional growth rod (Expedium 4.5 Spine System, Depuy Synthes). Costs were modelled from an NHS and personal social services perspective. The population included in the model was children aged 2 to 11 years with severe early-onset scoliosis. The model adopted a cost-minimisation approach based on an assumption of equivalent clinical efficacy between the MAGEC system and conventional growth rods. The model included the cumulative costs associated with initial surgery, device failure and rod lengthenings over a 6-year time horizon.

5.3 The model included 2 clinical parameters: device failure rate and frequency of lengthening. The sponsor used a device failure rate of 0% for both the MAGEC and conventional growth rods in its base-case analysis, based on clinical evidence. Frequency of lengthening was assumed in the model to be 3-monthly for the MAGEC system. Conventional growth rods were assumed to be lengthened every 6 months.

5.4 The sponsor took most of the resource use figures for its model from the study by Richards and Nnadi (2013). The cost of device failure in the sponsor's model was estimated to be around £11,000 less than the cost of initial insertion for both the MAGEC system and conventional growth rods, based on complete replacement of the rods. This cost included device costs and surgical time only and did not take into account other costs incurred such as pre- or post-operative care. A cost per lengthening was also included, based on an average of 2 figures taken from an NHS trust and from Richards and Nnadi (2013) for the MAGEC system and from Richards and Nnadi (2013) only for conventional growth rods. These costs are currently academic-in-confidence and cannot be reported here.

5.5 The sponsor carried out sensitivity analyses by varying the device failure rate. The device failure rate was 0% in the base-case analysis and 8.8% and 17.2% in 2 scenario analyses. All device failures were assumed to occur in the first month only. A third sensitivity analysis was included, using a device failure rate of 8.8% with an additional failure rate for conventional growth rods of 176% per child at month 13, based on a study by Yang et al. (2011). The External Assessment Centre noted that this figure was calculated based on the total number of rod fractures in children experiencing any rod fractures (86 fractures in 49 children), and not the study population as a whole (327 children), which would give an overall rod fracture rate of 15%.

5.6 The results of the sponsor's base case suggested that the MAGEC system was cost saving at 6 years, with a break-even point 39 months after initial insertion. From the sponsor's model, the cost saving for the MAGEC system compared with conventional growth rods at 6 years was £9946. Results of the sensitivity analysis indicated that the model was robust and the MAGEC system remained cost saving over the 6-year time horizon. The month of break-even varied from 28 to 45 and the cost savings ranged from £8109 to £12,984.

5.7 The External Assessment Centre considered that the sponsor's model used an appropriate treatment pathway and captured key aspects of treatment. However, it noted a weakness of the model was the assumption of clinical equivalence between the MAGEC system and conventional growth rods. The External Assessment Centre considered that the available evidence did not support this assumption.

5.8 The External Assessment Centre also considered that many of the inputs to the sponsor's model were incorrect. In some instances it judged that the sponsor had taken the wrong cost from Richards and Nnadi (2013), and in others that the Personal Social Services Research Unit (2012) unit costs of health and social care would have been more accurate. Sensitivity analyses were only carried out on 1 parameter in the sponsor's model and no adverse events other than complete device failure in the first month were considered. The External Assessment Centre considered that the costs for insertion should also be used when device failure occurred. The External Assessment Centre also noted that no discounting was applied in the sponsor's model.

5.9 The External Assessment Centre revised the sponsor's model to address some of the limitations identified:

- A monthly device failure rate was applied throughout the 6-year time horizon, taken from clinical evidence.
- Surgical site infections were also included in the model. The infection rate was taken from clinical evidence and included at month 0 for the MAGEC system and as a monthly rate for conventional growth rods to account for lengthening procedures.
- The difference in the proportion of dual and single rods was introduced into the model for both systems, based on the proportions used in the clinical evidence. Dual rods were assumed to be used in 65% of children with scoliosis and costs were weighted accordingly.
- A proportional cost for distraction was included at each month to allow for wider sensitivity analysis. Distraction was assumed to take place every 3 months for MAGEC and every 6 months for conventional growth rods.
- The costs for initial rod insertion and for complete device failure were assumed to be the same. This was calculated as £27,431 for the MAGEC system and £15,270 for conventional growth rods.
- Costs were discounted by 3.5% in line with the NICE medical technologies evaluation methods guide.

5.10 Results of the base case in the revised model showed that the MAGEC system generated cost savings of £12,077 after 6 years compared with conventional growth rods. The findings showed that the MAGEC system would become cost saving at month 35 after insertion.

5.11 The External Assessment Centre carried out extensive 1- and 2-way sensitivity analyses on most of the model inputs. This included varying: the costs and months between distractions, cost and rate of device failure, costs of insertion and device failure for each system, and costs and rates of infection.

5.12 The results of the 1-way sensitivity analysis showed that the cost difference was most sensitive to the cost of and interval between distractions for conventional growth rods. Varying the cost of conventional growth rod distraction to its lowest value, £1133, led to the MAGEC system incurring costs after 6 years.

Varying the months between distractions indicated that the MAGEC system would incur costs if the interval between conventional growth rod distractions was 10.2 months or more. Expert advice obtained by the External Assessment Centre was that conventional growth rod lengthening generally occurs at 6-monthly intervals in the NHS and so this would make the MAGEC system likely to be cost saving. In all other scenarios examined, the MAGEC system remained cost saving.

5.13 In the 2-way sensitivity analyses, varying the cost of conventional growth rod lengthening to the lower range of values and increasing the months between distractions caused the MAGEC system to become cost-incurring. This is consistent with results from the 1-way sensitivity analysis. According to the model, if conventional growth rod distractions were carried out every 6 months, the cost of distraction surgery would have to be below £1579 per episode before the MAGEC system incurred costs. Based on clinical advice and cost data, the External Assessment Centre judged that the average cost of distraction surgery was unlikely to be this low in practice.

5.14 Lowering the insertion cost of conventional growth rods and raising it for the MAGEC system caused the MAGEC system to become cost-incurring. However, the External Assessment Centre obtained expert advice which indicated that, in practice, the resource use for initial insertion of MAGEC system rods was likely to be equivalent to that of conventional growth rods. Therefore, it was unlikely that the cost of inserting the MAGEC system would be so much more than the cost of inserting conventional growth rods that it would become cost-incurring. The External Assessment Centre judged it unlikely that the cheapest available conventional growth rods would be used in all instances, also based on clinical expert advice.

5.15 The External Assessment Centre also varied the time horizon for the model in light of advice from 2 clinical experts who stated that the overall treatment time would vary depending on the child's age at the start of treatment and the time to achieve spinal maturity. Furthermore, rods may need replacement if the child's spinal growth exceeds the maximum lengthening capacity of the rods. The External Assessment Centre carried out analysis to explore the impact of replacing rods at different time periods between 3.5 and 5 years after initial insertion. Both systems were assumed to be replaced in the same month. Rod replacement meant that the MAGEC system would become cost saving at

around 68 months (5.5–6 years) after initial insertion. If the duration of treatment was longer, the cumulative cost savings would increase over time. The findings also suggested that the MAGEC system would generate cost savings if used to replace conventional growth rods in children with more than 35 months of growth potential remaining. The External Assessment Centre judged that based on clinical and economic evidence and clinical expert advice, the typical length of treatment using growth rods is likely to be 35 months or longer. This indicates that the MAGEC system would be cost saving when compared with conventional growth rods, as in the base case.

5.16 The External Assessment Centre concluded that many of the uncertainties around the model inputs had been addressed in the sensitivity analysis and that the results of the base case were robust. The External Assessment Centre also noted that the results from the revised model were similar to the sponsor's base case despite revisions to many of the inputs. However, the External Assessment Centre acknowledged that the model assumed clinical equivalence between the MAGEC system and conventional growth rods when the available clinical evidence could not inform this assumption. It also noted that many of the model costs were taken from 1 unpublished study (Richards and Nnadi 2013), which may not be generalisable because this study was set in a single centre.

Committee considerations

5.17 The Committee noted that the revisions to the model prepared by the External Assessment Centre relied on costs from 1 unpublished study. However, the Committee considered that the extensive sensitivity analyses conducted by the External Assessment Centre and the expert advice it sought, addressed many of the uncertainties in the economic evidence. The Committee judged the findings from these revisions to be sufficiently robust to allow a decision to be made and concluded that cost savings were likely to be realised in practice.

5.18 The Committee heard expert advice that the frequency of distractions using the MAGEC system may increase in future as clinical use of the product develops. The External Assessment Centre therefore recalculated the findings from the revised model using a 6-week distraction interval and concluded that even with more frequent distractions, the MAGEC system would still generate cost savings of more than £7000 over the 6-year time horizon.

5.19 The Committee considered the impact of the potential reduction in spinal cord monitoring during rod lengthening procedures (see section 4.5), which had not been considered in the sponsor's model. The External Assessment Centre investigated the use of spinal cord monitoring in conventional rod lengthenings and found variation in practice, with some centres using it routinely and others not using it at all. It also found that the modality of spinal cord monitoring varied. Through a review of the available literature, the External Assessment Centre identified a range of spinal cord monitoring costs. It subsequently incorporated these costs in the revised model for all conventional growth rod lengthenings. It found that not using spinal cord monitoring for MAGEC system rod lengthenings would generate cost savings of £13,170 per child over the 6-year time horizon if spinal cord monitoring cost £120 per lengthening procedure (the lowest cost identified), or £15,327 per child if it cost £343 per lengthening procedure (the highest cost identified). The Committee concluded that the base-case saving of around £12,077 per child after 6 years was likely to be conservative because it did not include the impact of these costs.

5.20 The Committee noted that it may not be cost saving to use the MAGEC system in older children with less than 35 months' growth potential, because the system is estimated to become cost saving only after about 35 months. The Committee judged that use of the system in older children would need careful patient selection, with consideration of individual circumstances and benefits.

6 Conclusions

6.1 The Committee concluded that the available clinical evidence, together with expert clinical advice and technical information, showed that the MAGEC system is an effective treatment for children with scoliosis for whom surgery is considered necessary. The Committee also concluded that the MAGEC system is likely to provide benefits compared with the use of conventional growth rods. These benefits would arise from avoiding repeated surgical procedures for growth rod lengthening, which would reduce pain and psychological distress, shorten hospital stays, and result in less time away from usual activities for children with scoliosis and their families or carers. In addition, the risk of complications such as infection would be reduced.

6.2 The Committee accepted the revised model and sensitivity analyses and concluded that the MAGEC system could generate substantial cost savings after about 3 years when compared with conventional growth rod treatment.
Sir Andrew Dillon
Chief Executive
June 2014

7 Committee members and NICE lead team

Medical Technologies Advisory Committee members

The Medical Technologies Advisory Committee is a standing advisory committee of NICE. A list of the Committee members who took part in the discussions for this guidance appears below.

Committee members are asked to declare any interests in the technology to be evaluated. If it is considered there is a conflict of interest, the member is excluded from participating further in that evaluation.

The minutes of each Medical Technologies Advisory Committee meeting, which include the names of the members who attended and their declarations of interests, are posted on the NICE website.

Professor Bruce Campbell (Chair)
Consultant Vascular Surgeon, Exeter

Dr Peter Groves (Vice Chair)
Consultant Cardiologist, Cardiff and Vale NHS Trust

Professor Dilly Anumba
Chair of Obstetrics and Gynaecology/Honorary Consultant Obstetrician and Gynaecologist, University of Sheffield

Ms Susan Bennett
Lay member

Dr Keith Blanshard
Consultant Interventional Radiologist, University Hospitals of Leicester NHS Trust

Mr Matthew Campbell-Hill
Lay member

Professor Daniel Clark
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Professor of Neurogastroenterology, University of Manchester

Dr Jerry Hutchinson
Independent Medical Technology Adviser

Dr Cynthia Iglesias
Health Economist, University of York

Professor Mohammad Ilyas
Professor of Pathology, University of Nottingham

Dr Greg Irving
General Practitioner and Clinical Lecturer, University of Cambridge

Dr Eva Kaltenthaler
Reader in Health Technology Assessment, ScHARR, University of Sheffield

Dr Paul Knox
Reader in Vision Science, University of Liverpool

Mrs Jacqui Nettleton
Programme Director, Commissioning, Western Sussex Hospitals NHS Trust

Professor Brian J Pollard
Professor of Anaesthesia, University of Manchester. Consultant Anaesthetist, Central Manchester University Hospitals

Mr Brian Selman
Managing Director, Selman and Co

Professor Wendy Tindale
Scientific Director, Sheffield Teaching Hospitals NHS Foundation Trust

Professor Allan Wailoo
Professor of Health Economics, School of Health and Related Research (ScHARR), University of Sheffield

Mr John Wilkinson
Director of Devices, Medicines and Healthcare Products Regulatory Agency

Dr Janelle Yorke
Lecturer and Researcher in Nursing, University of Manchester

NICE lead team

Each medical technology assessment is assigned a lead team of a NICE technical analyst and technical adviser, an expert adviser, a technical expert, a patient expert, a non-expert member of the Medical Technologies Advisory Committee and a representative of the External Assessment Centre.

Joanne Higgins
Technical Analyst

Bernice Dillon
Technical Adviser

Jeremy Fairbank
Lead Expert Adviser

Neil Davidson
Lead Expert Adviser

Jane Clarke
Patient Expert

Eva Kaltenthaler
Non-Expert MTAC Member

Joyce Craig
External Assessment Centre Representative

Michelle Jenks
External Assessment Centre Representative

8 Sources of evidence considered by the Committee

The External Assessment Centre report for this assessment was prepared by Newcastle upon Tyne Hospitals and York Health Economics Consortium:

- Craig J, Jenks M, Willits I et al. MAGEC system for spinal lengthening in children with early onset scoliosis, November 2013

Submissions from the following sponsor:

- Ellipse Technologies Inc.

The following individuals gave their expert personal view on the MAGEC system by providing their expert comments on the draft scope and assessment report.

- Mr Sashin Ahuja, ratified by the British Scoliosis Society – clinical expert
- Mr Colin Bruce, nominated by the British Society for Children's Orthopaedic Surgery - clinical expert
- Jane Clarke, nominated by the Scoliosis Association UK – patient expert
- Mr Neil Davidson, ratified by the British Scoliosis Society – clinical expert
- Professor Jeremy Fairbank, ratified by the Royal College of Surgeons of England - clinical expert
- Mr John Hutchinson, ratified by the British Scoliosis Society – clinical expert
- Mr Peter Milner, ratified by the British Orthopaedic Association – clinical expert
- Mr Colin Nnadi, ratified by the British Scoliosis Society – clinical expert (draft scope only)
- Mr Hilali Nordeen, ratified by the British Scoliosis Society – clinical expert

The following individuals gave their expert personal view on the MAGEC system in writing by completing a patient questionnaire or expert adviser questionnaire provided to the Committee.

- Mr Sashin Ahuja, ratified by the British Scoliosis Society – clinical expert
- Mr Colin Bruce, nominated by the British Society for Children's Orthopaedic Surgery - clinical expert

- Jane Clarke, nominated by the Scoliosis Association UK – patient expert
- Mr Neil Davidson, ratified by the British Scoliosis Society – clinical expert
- Professor Jeremy Fairbank, ratified by the Royal College of Surgeons of England - clinical expert
- Mr John Hutchinson, ratified by the British Scoliosis Society – clinical expert
- Mr Peter Milner, ratified by the British Orthopaedic Association – clinical expert
- Mr Colin Nnadi, ratified by the British Scoliosis Society – clinical expert
- Mr Hilali Nordeen, ratified by the British Scoliosis Society – clinical expert

About this guidance

This guidance was developed using the NICE medical technologies guidance process.

It has been incorporated into the NICE pathway on musculoskeletal conditions, along with other related guidance and products.

We have produced a summary of this guidance for the public. Tools to help you put the guidance into practice and information about the evidence it is based on are also available.

Related NICE guidance

For related NICE guidance, please see the NICE website.

Changes after publication

April 2015: Minor maintenance

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This guidance represents the views of NICE and was arrived at after careful consideration of the evidence available. Healthcare professionals are expected to take it fully into account when exercising their clinical judgement. However, the guidance does not override the individual responsibility of healthcare professionals to make decisions appropriate to the circumstances of the individual patient, in consultation with the patient and/or guardian or carer.

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