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World J Gastroenterol 2001;7(5):612-621
World Journal of Gastroenterology
 ISSN 1007-9327

• REVIEW •

The impact of new technology on surgery for colorectal cancer

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Received 2001-07-21 **Accepted** 2001-08-15

Abstract

Advances in technology continue at a rapid pace and affect all aspects of life, including surgery. We have reviewed some of these advances and the impact they are having on the investigation and management of colorectal cancer. Modern endoscopes, with magnifying, variable stiffness and localisation capabilities are making the primary investigation of colonic cancer easier and more acceptable for patients. Imaging investigations looking at primary, metastatic and recurrent disease are shifting to digital data sets, which can be stored, reviewed remotely, potentially fused with other modalities and reconstructed as 3 dimensional (3D) images for the purposes of advanced diagnostic interpretation and computer assisted surgery. They include virtual colonoscopy, trans-rectal ultrasound, magnetic resonance imaging, positron emission tomography and radioimmunoscintigraphy. Once a colorectal carcinoma is diagnosed, the treatment options available are expanding. Colonic stents are being used to relieve large bowel obstruction, either as a palliative measure or to improve the patient's overall condition before definitive surgery. Transanal endoscopic microsurgery and minimally invasive techniques are being used with similar outcomes and a lower mortality, morbidity and hospital stay than open trans-abdominal surgery. Transanal endoscopic microsurgery allows precise excision of both benign and early malignant lesions in the mid and upper rectum. Survival of patients with inoperable hepatic metastases following radiofrequency ablation is encouraging. Robotics and telemedicine are taking surgery well into the 21st century. Artificial neural networks are being developed to enable us to predict the outcome for individual patients. New technology has a major impact on the way we practice surgery for colorectal cancer.

Subject headings colorectal neoplasms; technology; surgery; radiology

Makin GB, Breen DJ, Monson JRT. The impact of new technology on surgery for colorectal cancer. *World J Gastroenterol*, 2001;7(5): 612-621

INTRODUCTION

Advances in technology continue at a rapid pace and affect all aspects of life. Medicine is no exception. Colorectal carcinoma (CRC) is the third most commonly diagnosed cancer in the western world[1]. There have been considerable steps forward in the survival and outcome of CRC in recent years. New technology has in no small way contributed to this improvement. One of the major advances in surgery in the 20th century was the development of circular stapling devices in Russia in 1967[2]. These instruments have revolutionized the colorectal anastomosis, particularly deep in the pelvis and almost certainly contributed to the increase in sphincter preserving operations. Another was the introduction of minimally invasive techniques, which has altered the approach to many surgical procedures. Imaging investigations are shifting from analogue film storage to digital data sets. Once acquired this imaging data can be stored, reviewed remotely, potentially fused with other modalities and reconstructed as 3 dimensional images for the purposes of advanced diagnostic interpretation and computer assisted surgery. There will be an increased reliance on 3D-imaging in all aspects of patient care[3]. Now that we have entered the 21st century, how will these and other new technologies affect the practice of coloproctology The AIM of these advances is to continue to improve the outcome of patients with CRC, by altering the way physicians diagnose and treat their diseases. We discuss a number of new technological advances and their impact on surgery for CRC (Table 1).

Table 1 New technology available for colorectal surgeons

INVESTIGATION	
	Modern endoscopes
	Virtual colonoscopy
	Trans-rectal ultrasound
	Magnetic resonance imaging
	Positron emission tomography
	Radioimmunoscintigraphy
INTERVENTION	
	Colonic stents
	Transanal endoscopic microsurgery
	Minimally invasive surgery
	Radiofrequency ablation
	Robotics
OUTCOME	
	Artificial neural networks

INVESTIGATION OF COLORECTAL CANCER

The management of CRC relies on its early detection and characterization. Improving the outcome of CRC depends not only on sensitive investigations but also the encouragement of early presentation by symptomatic patients and population screening. Currently, fibre optic endoscopy is the investigation of choice for the diagnosis of CRC. New colonoscopes are being developed with improved optics, magnifying and localisation capabilities and dual channels allowing endoscopic resection and endoscopic assisted surgery. Endoscopy though, is invasive and carries a small risk of perforation of around 0.2%[4]. Virtual colonoscopy is being developed which will alleviate this risk and still examine the entire colon in 3-dimensions. There are many treatment modalities available once CRC has been diagnosed. The best option for an individual patient depends on the stage of the disease and the surgeon's expertise. Ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and radioimmunoscintigraphy can all be used to diagnose tumours, provide staging information pre operatively and detect recurrence. Improvements in the sensitivity of these investigations will result in a better outcome for patients.

Modern endoscopes

Fibre optic endoscopy and biopsy remains the investigation of choice for examining the colon and diagnosing CRC. Unfortunately in the United Kingdom a complete colonoscopic examination to the caecum is achieved in only 70% of cases[5]. This results in the patient having to make another visit to the hospital for either a repeat colonoscopy or a completion barium enema. Incomplete colonoscopy is usually due to a combination of looping of the scope, redundant or angulated sigmoid colon and patient intolerance. Several different configurations of looping are possible in the colon, including alpha, gamma, and N loops. Many of these require a different manoeuvre to un-loop the scope. Magnetic imaging localisation and variable stiffness endoscopes are being developed to reduce these loops forming and aid in their reduction, making the procedure more comfortable for the patient and improving the success rate of a complete examination of the colon. Magnifying endoscopes can help differentiate between neoplastic and non-neoplastic lesions without the need for histologic examination. As a result, the overall efficiency of colonoscopy should improve.

The position of the colonoscope within the colon and presence of any looping can be demonstrated using real time 3-dimensional magnetic imaging, which is built into the scope. Shah[6] has shown that even in the hands of expert endoscopists, correct identification of loop configuration occurred only 31% of the time. As the image generated is in real time, loops can be detected and straightened as soon as they form, resulting in shorter intubation time and higher completion rates[7]. Appropriate position change of the patient or a bdominal pressure can be used to correct to loop, if it's configuration is known. The magnetic imaging endoscope can also be used to indicate the extent of the examination. It has the advantage over fluoroscopic screening of having no radiation exposure to either the patient or endoscopy staff. However, identification of the ileocaecal valve, appendix orifice or ilealmucosa remains the gold standard of assuring complete examinati on of the colon. Not only are these new scopes good for patient care, but they are a useful tool for teaching as it shows the trainee exactly what is happening to the scope inside the colon. This feedback gives the operator a better understanding of how loops form, how this changes the resistance of scope insertion and how to prevent and straighten these loops. Shah[7] has shown that trainees using the MR imaging colonoscope have a higher completion rate and spend less time looping the instrument. As a result we should have more proficient endoscopists in the future.

Another new development is a variable stiffness colonoscope. The endoscopist can increase the stiffness of the scope, which reduces looping. Brooker[8] in a randomised control trial has found significantly quicker caecum intubation time (7 *vs* 11 minutes) and less patient discomfort (median pain scores 7 *vs* 24) when using this scope compared with a conventional colonoscope. As a result the rate of incomplete examinations should decrease and patient satisfaction increase.

Currently colonic polyps are biopsied or removed for histological diagnosis to determine if they are neoplastic. Patients with neoplastic lesions require ongoing surveillance, while those with non-neoplastic lesions can be reassured of their low risk of CRC and discharged. The complication rate with colonic biopsy is around 0.5% and includes bleeding, perforation and trans-mural thermal injury[9]. The crypt pattern of polyps has been shown to predict their underlying histology[10]. Magnifying endoscopes are being used to examine t he crypt patterns of polyps. Togashi[11] used a 100 times magnifying scope to examine the crypt pattern of 923 polyps following dye spray. The crypt or ifices were classified into 6 categories: medium round, asteroid, elliptical, small round, cerebriform and no apparent pattern. The first 2 were considered to be a non-neoplastic lesion, while the remainder was neoplastic. Neoplastic and non-neoplastic lesions could be distinguished by the crypt pattern in 88%, when compared to their histological diagnosis. With the use of the magnifying scope in the future, non-neoplastic lesions may not need to be biopsied. Advances in endoscopes will enable more complete and less painful examination of the colonic mucosa, with more accurate evaluation of polyps and a lower overall morbidity, making colonoscopy an even more valuable investigation.

Virtual colonoscopy

Virtual colonoscopy, CT colography CT colonography and CT pneumocolography are all terms which have been used to describe essentially similar investigations. It was first reported by Vining in 1994. Advances in CT software and hardware, particularly the advent of helical data acquisition, have enabled rapid high resolution 2 and 3-dimensional images of the colon to be created. The majority of colonic lesions can be detected on the standard 2-dimensional data set, while the 3-dimensional data is used for problem solving by simulation of an endolu minal image. However, Hara[12] reported that the accuracy of this test is superior when both the 2-D and 3-D images are reviewed, compared to the 2-D images alone. After the patient has taken mechanical bowel preparation, the clean colon is distended with 1.5 L-2 L of air or carbon dioxide, via a rectal catheter. This technique has several advantages. Firstly it is a rapid examination, with the volumetric CT data acquisition taking only a few minutes. It is non-invasive (apart from the introduction of a rectal catheter) and is performed without the need for sedation or abdominal compression. Virtual colonoscopy can examine other abdominal organs, avoids the 1 in 1000 risk of perforation by colonoscopy and is well tolerated by patients. Hara[12] reported that patients were more comfortable during virtual colonoscopy than with barium enema or colonoscopy. The imaging data can then be viewed and manipulated at a remote works station at a convenient time. The disadvantages of virtual colonoscopy are that histological specimens cannot be taken and at present, mucosal detail is poor, relying mostly on polypoidal morphology for lesion detection. Data interpretation can be time consuming, particularly if 3-D reconstruction is required.

Initially the main limitation of this investigation was a difficulty in distinguishing small polyps from faecal residue and examining collapsed segments of colon. The addition of prone imaging to the routine supine imaging has largely overc ome this problem, with improvement in the detection of polyps 5 mm in size or greater, from 75% to 88%[13]. Recent years have seen developments in spatial resolution and image manipulation such as colon mapping. The colon is "digitally straightened" and opened for purposes of analysis of the colonic mucosal surface. In addition bowel preparation which permits the tagging of faecal residue and subsequent digital subtraction of these artifacts should lead to enhanced polyp detection. Currently the accuracy of polyp detection by virtual colonoscopy is superior to barium enema and is approaching conventional colonoscopy. Results are dependent on polyp size. A large randomised control trial of 180 patients, with 420 colonoscopically proven polyps, showed virtual colonoscopy to have a sensitivity and specificity of 85% and 93% respectively of detecting polyps 1 cm or more in size and 88% and 72% of detecting polyp s 5 mm or greater[13]. Fenlon reported that both virtual and conventional colonoscopy had a similar rate of complete examination of the colon (87% and 89% respectively). The former detected 89% of polyps greater than 6 mm[14].

The problem with conventional endoscopy remains incomplete examination of the pr oximal colon, either due to an occlusive lesion or patient intolerance. Virtual colonoscopy has the ability to examine the proximal colon above an obstructing o r impassable lesion. Morrin[15] compared virtual colonoscopy with bariu m enema in 40 patients who had a failed endoscopy. Virtual colonoscopy had significantly better views of all colonic segments and was better tolerated by the patient. The right colon is easier to evaluate than the sigmoid colon because a greater degree of distension is achievable and it lacks muscle spasm and hypertr ophy. Endoscopic blind spots behind mucosal folds are eliminated by virtual colonoscopy as the 3-D "fly through" can be done in both directions.

Virtual colonoscopy has the advantage of being able to examine the other organs in the abdomen and pelvis at the same time as the colon. Cross sectional views of the colon can show the wall thickness. Evidence of enlarged lymph nodes and liver involvement can be obtained. Morrin[16] correctly staged 13 out of 16 CRC's. Imaging of the liver makes it an efficient use of resources as many patients with a carcinoma have hepatic imaging to stage their disease. Much of the necessary pre operative data can be obtained in one visit with virtual colonoscopy. The uncovering of unrelated asymptomatic pathology has evoked some controversy. Hara[12] found highly clinically important secondary pathology in 11% of patients, including asymptomatic aortic aneurysms. The detection of other potentially life threatening diseases, which are common in this age group, can only be beneficial.

Virtual colonoscopy may revolutionise population screening for CRC as it is edging towards most of the factors needed for a screening tool. It is quick, non invasive, has a high patient acceptance, minimal morbidity, increasing sensitivity and can screen for several diseases at once. At present though, there are no reports in the literature on its use as a screening modality.

Trans-rectal ultrasound and magnetic resonance imaging

The importance of accurate pre operative staging of rectal cancer has grown with the increasing number of treatment options available. These include, local resection, trans abdominal resection, pre operative down staging and palliative radiotherapy. Benign or early malignant (pT1) rectal lesions can be excised locally. Patients with stage pT3 and pT4 tumours benefit from pre operative radiotherapy[17]. Asymptomatic or elderly patients with distant metastases may be given palliative chemoradiotherapy. Accurate pre operative staging of rectal cancer is thus essential in the planning of optimal therapy. Clinical examination, trans abdominal and trans-rectal ultrasound (TRUS), CT, phased-array pelvic body coil and endo-rectal MRI scanning are all used in some combination to assess the depth of rectal wall tumour invasion, and the presence of lymph no de and distant metastases. Despite these modern investigations, the "educated" digital rectal examination remains an important part of the assessment of recta l lesions, particularly in assessing tumour fixity and the need for down staging pre operative radiotherapy[18].

TRUS and MRI are currently both being used clinically in the pre operative assessment of rectal lesions. Both modalities can assess the depth of rectal wall invasion by the primary tumour and detect enlarged lymph nodes, suggesting tumour involvement. MRI has an advantage that it can simultaneously examine the liver for distant metastases. Unlike CT, there is no radiation risk to the patient with either modality. Many studies have shown that TRUS and MRI are more sensitive than CT in staging rectal lesions[19,20]. However, there are conflicting reports as to which of these 2 former investigations is the most accurate in determining the depth of invasion. This in part depends on the MRI technique, whether a surface (phased-array) or an endo-rectal coil is used and is operator dependent. Satoh[21] found TRUS more accurate than MRI, while Thaler[22] and Waizer[23] found no difference between the two. In two recent prospective comparative studies there was no significant difference between TRUS and endo-rectal MRI in both T and N[24] (Tables 2 and 3). Drew[25] highlighted the problem of inter-observer variation with only 31% accuracy in assessing depth of invasion. The accuracy of pre operative staging continues to improve as refinement and understanding of the MRI technique improves. Brown[26] has achieved a 100% T-staging accuracy, predicting depth of extramural tumour invasion to within 5 mm, with the use of high resolution phased-array pelvic coil MRI.

Results of lymph node staging are also conflicting,with neither investigation consistently showing a high level of accuracy. Thaler[22] found TRUS mo re accurate than MRI (80% versus 60%). Using MRI, McNicolas[27] reported a 95% accuracy, where as Drew[25] reported only a 58% positive predictive value. While TRUS and MRI are both reasonably sensitive at staging the depth of tumour, MRI is better at assessing tumour extension into adjacent organs. Both MRI and TRUS rely on highly skilled interpretation of the images, with the former being more expensive and the latter user dependent.

Hepatic metastases can be detected either by ultrasound, CT or MRI. Although ultrasound is quick and easy, MRI is the most sensitive by virtue of enhanced contrast resolution, with an accuracy of 81% in detecting liver[28]. The time has passed when the only pre operative staging of a rectal lesion was with the educated digital rectal examination. Pre-operative staging continues to improve with Brown[26] achieving a 100% T-staging accuracy with the use of high resolution phased-array pelvic coil MRI. Such technological developments will continue to slowly enhance patient outcome, as accurate pre operative staging will triage patients to the appropriate treatment.

The usefulness of intense follow up programs after curative CRC resection remain s controversial. Survival benefits have not been shown in a randomised control trials comparing intensive follow up to no follow[29]. Tumour recurrence is often diagnosed late, with less than 30% amenable to further curative surgery[30]. This recurrence is usually a marker of advanced disease. Radiologic pelvic surveillance is hindered by its inability to distinguish tumour recurrence from post operative fibrosis. Dynamic contrast enhanced MRI is still clAIMed to be the most accurate means of detecting early recurrent disease in the pelvis[21,23].

Table 2 Rectal cancer staging by TRUS and MRI[24]

	TRUS (%)	MRI (%)
T stage accuracy	80	85
N stage sensitivity	72	81
N stage specificity	80	66

Table 3 Rectal cancer staging by TRUS, MRI and CT[20]

Accuracy of detection	TRUS (%)	MRI (%)	CT (%)
Depth of invasion	81	81	65
Lymph node metastases	63	63	56

Positron emission tomography

Positron emission tomography (PET) was first applied to CRC in 1982. PET detects abnormal cellular metabolic activity. PET utilises a number of radiolabelled an alogues, including F-18-FDG, which are preferentially concentrated in malignant cells due to their accelerated glycolysis. F-18-FDG decays by positron emiss ion, which releases 2 protons, which are detected by the imager. Ultrasound, CT and MRI rely largely upon morphologic changes to detect tumour recurrence. The a dvantage of PET is that these cellular changes precede any structural abnormality. There have been 2 large studies showing PET to be more sensitive in detecting recurrent CRC than conventional imaging. Valk[31]reported a sensitivity of 93% *vs* 69% and a specificity of 98% *vs* 96% of PET versus CT respec tively. Whiteford[32] found similar results when comparing PET with CT and colonoscopy combined (sensitivity 90% *vs* 71% and specificity 92% *vs* 85% respectively). PET has detected unsuspected metastases in up to 32% of patients with normal[33,34]. The sensitivity and specificity of PET versus CT in detecting extrahepatic metastases is 94% *vs* 67% and 98% *vs* 96% respectively. As a result there should be a reduction in the number of unnecessary laparotomies, which should help to offset the high purchase cost of the PET hardware. In the future PET may also have a role in evaluating tumour response to chemotherapy and radiotherapy. Findlay[35] reported that the rate of uptake of F-18-FDG in CRC liver metastases compared to normal liver could discriminate tumour response from non-response to fluorouracil.

The main disadvantage of PET is its inability to distinguish between tumour and inflammation. PET has increased uptake in the setting of acute inflammation. This may be the reason for the high false positive rate reported by Schiepers[36], who had 11 false positive results in the chest out of 25 positive tests. Likewise, assessing the response of CRC to radiotherapy is limited by the inflammatory response it produces. This may decrease as experience with this modality increases.

The current role of PET in the management of CRC remains unclear. Early benefits have been shown in detecting recurrent and metastatic disease. Fusing the information it yields with CT and MRI images is enhancing its diagnostic interpretation. There are few reports of its use in screening and detection of primary lesions. Other disadvantages of PET include its limited availability and high cost (around 1.5 million capital cost) and tracer production and distribution.

Radioimmunoscintigraphy

Radioactive labelled antibody scans are being used in many aspects of medicine today. Like PET it detects cellular abnormalities prior to any structural change s in the tissues. There have been many monoclonal antibodies developed to detect CRC antigens, with sensitivity ranging from 74% to 92%. These antigens include B72.3, carcinoembryonic antigen (CEA), BW431/21 and PR1A3[37-40]. CEA molecules break off the colonic columnar cell membrane and circulate in the blood stream. This shed antigen significantly reduces the accuracy of CEA scanning. In contrast, PR1A3 is an anti-CEA monoclonal antibody that binds preferentially to columnar cell surface bound CEA rather than soluble CEA found in circulating[41]. Technetium labelled PR1A3 has been shown to detect 100% of primary CRC's. At present however, colonoscopy remains the investigation of choice for detecting primary lesions, although 99m-Tc PR1A3 is being used clinically to detect recurrent CRC, with a sensitivity and specificity of 96% and 50% respectively[42]. Despite the realization that it is difficult to detect recurrence early enough to be curable, in this study 25% had a beneficial alteration in their management plan.

Despite modern radiology and endoscopy, the aetiology of a recto-sigmoid mass or stricture may remain undiagnosed. Every surgeon has been in the dilemma of whether the lesion is malignant or diverticular in origin. The timing and extent of the resection is determined by the underlying aetiology. Malignant lesions require early surgery with radical en-bloc resection, while diverticular disease should have an initial conservative approach, followed by a limited resection when the inflammation has resolved. Ongoing efforts are concentrating on whether PR1A3 can differentiate between malignancy and inflammatory conditions and early results are encouraging[43]. Overall therefore, the role of radio immunoscintigraphy in the management of CRC seems likely to continue to expand as new, more specific antibodies are developed.

MANAGEMENT OF COLORECTAL CANCER

Colonic stents

The management of a malignant large bowel obstruction in the acute setting, in t he elderly with co-morbidity and those with unresectable disease remains problematic. A new treatment option, the expanding metallic stent, was first reported by Itabashi[44] in 1993. They can be used to relieve obstruction prior to surgery or as palliation and are inserted either with fluoroscopic or endosc opic guidance. Preoperative stenting of large bowel obstructions relieves sympto ms in 87%-100% within 96 hours[45-47]. Stenting AIMs to allow time for the patient's overall medical condition to improve. This reduces the complexity and number of stages of the surgery, with 90% of patients able to undergo an elective single stage procedure[47,48]. The short-term benefits of stenting are obvious, but we do not know of any long-term risks, such as tumour fracture and dissemination. If the procedure can be shown to be safe, then all patients should have a stent placed to improve their nutritional status, electrolyte balance and permit bowel preparation prior to surgery. All these factors will reduce mortality and morbidity and the number of defunctioning stomas required. The main risk of the procedure is perforation of the colon, but this is usually recognised early and patients can proceed to surgery, reverting to a conventional treatment plan. Law[46] reported a series of 24 malignant large bowel obstructions, with 1 perforation requiring a Hartmann's procedure and 3 patients later requiring a stoma. Turegano-Fuentes[49] reports severe tenesmus in 2 patients where the stent was placed low in the rectum.

Palliative stenting of advanced colorectal carcinoma is a quick, effective and non-invasive way of relieving symptoms. It avoids both a laparotomy and a stoma in a patient with a life expectancy of less than 12 months. At present the role of stents in the management of resectable colon cancer remains uncertain. Stent design and technology and appropriate patient selection is continually evolving, making this a rapidly changing field. Overall results in the literatur e are variable and have mostly been confined to palliation. A prospective randomized trial comparing stenting with primary surgery in resectable disease is clearly required. Further studies need to be done into patient selection for stenting and timing of subsequent resection.

Minimally invasive surgery

Minimally invasive techniques have gained popularity over the past two decades, especially for upper gastrointestinal and biliary pathology. Laparoscopic cholec ystectomy has revolutionised biliary surgery and it is regarded as the procedure of choice for gallstones. Schlinkert[50] performed the first laparosco pically a ssisted hemicolectomy in 1991. Colorectal surgeons have been more cautious in ad opting laparoscopic techniques, particularly for malignant disease. Concern over the ability to perform safe dissection with adequate oncologic tumour and lymph node resection, intracorporeal anastomosis and port site recurrences has led regulating bodies in both the United Kingdom (National Institute for Clinical Exce llence) and United States of America (National Cancer Institute) to recommend that laparoscopic resections for CRC be restricted to clinical trials only. The advantages of minimally invasive surgery are well documented and include statistically significant less post operative pain, a reduced post operative ileus, a shorter hospital stay, better cosmesis and an earlier return to normal activity (Table 4)[51-53]. There is no difference in the cancer related outcome in experienced hands. In randomized control trials comparing laparoscopic and open colectomy, there was no difference in the length of colon, margin distance, length of mesentery and number of lymph nodes excised[54]. There is also no difference in 2 year recurrence free and crude survival rates[55]. Concern over the initially high rate of port site recurrences of up to 26% has not been sustained[56]. Since 1993, fifteen papers on port site recurrences have been published. Rates range from 0% to 1.7%, with a mean of only 0.65%. The threelargest series have a rate between 0.65% and 1.1%[57-59]. This is similar to the reported wound recurrence rates of 0.6% and 0.8% after open resection[60,61]. The cause of port site recurrence is still unknown, although Whelan[62] has suggested that they may be related to the "learning curve" phenomenon. Many patients, in both the laparoscopic and open groups however, had signs of disseminated intra abdominal disease. This fact is believed to be a more signifi cant risk factor for wound recurrence rather than the method of access. Over the years a number of preventative measures have been put forward to reduce recurrence, including the use of wound protectors, gasless laparoscopy, wound excision and peritoneal irrigation.

The advantages of laparoscopic resection for CRC is more pronounced in procedure s which do not require an incision to remove the specimen and perform the anasto mosis. An abdomino-perineal resection is an ideal laparoscopic case as the specimen is removed through the perineal wound and an end colostomy is created through a port hole. Darzi[63] suggests that better views of the mesorectal plane can be obtained using the laparoscope, allowing more precise dissection.

There is no doubt that minimally invasive surgery for CRC is safe, feasible and beneficial for the patient. It should however be limited to experienced laparoscopic and colorectal surgeons, with a low threshold for conversion to an open procedure. Patience is required as it usually takes longer to perform the procedure laparoscopically, especially in the beginning. Surgical principles of oncologic resection must not be compromised by the laparoscopic approach.

Table 4 Advantages of laparoscopic colectomy compared to open colectomy

Mean	Laparoscopic colectomy	Open colectomy
Narcotic use (days)	2.7	4.8
Ileus (days)	3.9	5.9
Hospital stay (days)	6.5	10.2

Transanal endoscopic microsurgery

Transanal endoscopic microsurgery (TEMS) was first performed by Buess[64] in 1983 in Germany. It has revolutionised local resection of rectal lesions, particularly malignant and those in the upper rectum. Traditionally, trans anal resection was limited to benign disease in the low and mid rectum. Many surgeons find this surgery cumbersome, with difficult access and poor views of the operating field. This usually limits its use to small lesions, usually less than 4cm diameter, within 6 cm-8 cm from the anus[65]. Surgery, with a curative intent, for malignant or upper rectal lesions, previously required trans-abdominal resection if endoscopic resection was not feasible. Mortality following trans-abdominal resection is around 5%-8%, but increases to 20% in patients over the age of 80[66]. Operative morbidity is around 25%[67].

There are two main advantages of TEMS in benign rectal disease. Firstly it allow s access to lesions in the mid and upper rectum. In two series of TEMS resection s most of the lesions would have been too high for a trans anal approach without TEMS, as the mean distance of the lesions from the dentate line was greater than 7 cm (Table 5)[68,69]. Secondly the local recurrence rate after TEMS (5%-9%), is much lower than traditional trans-anal resection (12%-25%)[70]. We feel that this low recurrence rate is due to the technique, as the rectum is constantly dilated by insufflation of CO_2 gas, enabling more precise surgery.

Table 5 TEMS excision of benign lesions[68,69]

	Lev-Chelouche	Neary
Number	46	21
Distance from dentate line (cm)	3-18 (mean 7)	5-17 (mean 10)
Size (cm)	1- 7 (mean 2.5)	2-12 (mean 3.9)
Recurrence	4 (9%)	1 (5%)

The use of local excision for malignant rectal lesions remains controversial. Willett[71] reported no difference in the outcome of pT1 and pT2 carcinomas, having favourable histologic features, resected trans-anally or trans-abdominally. The 5 year recurrence free rates were 87% and 91% respectively. Mellgren[72], on the other hand, reports a worse outcome with local resection when compared with trans abdominal resection. Overall 5 year survival rates were 69% and 82% respectively and local recurrence rates were 28% and 4% respectively. Mellgren however, did not exclude poorly differentiated lesions from trans anal excision, nor analyse the results of histological grade subgroup s. Also, these resections were performed using the less precise traditional trans-anal approach. The disadvantage of TEMS in malignant disease is the lack of lymph node sampling and clearance. The incidence of nodal involvement in pT1 tumours with a favourable histological grade is only 3%, compared to 12% in pT1 lesions with poor prognostic grade[73,74] advocated TEMS for pT1 lesions due to lower morbidity, similar local recurrence rates and similar survival benefit to that of a major resection . We feel that TEMS is a suitable alternative treatment option for pT1 and pT2 lesions with favourable histology. It can also be used in more advanced lesions and those with unfavorable histology in the elderly or those unfit for major surgery[69]. Results of TEMS for rectal malignancy are shown in Table 6. By carefully selecting the patients who undergo local excision for a malignant rectal lesion, acceptable results in overall survival and local control can be achieved. Neary[69] reports no recurrence after a mean follow up of 20 months, which is better than 3% local recurrence after total mesorectal excision[75].

Table 6 TEMS excision of malignant lesions[68,69]

	Lev-Chelouche	Neary
Number	29	19
Distance from dentate line (cm)	3-15 (mean 8)	4-14 (mean 10)
Size (cm)	2-5 (mean 3.2)	1-6 (mean 3.2)
Recurrence	4 (18%)	0 (0%)

Mortality and morbidity rates of TEMS are less than 1.3% and 20% respectively. This extremely low mortality makes it a very valuable alternative to a trans-abdominal approach, provided the cancer related outcomes remain equal. Most of the morbidity is minor and include urinary retention and haemorrhage managed conservatively. Intra-peritoneal perforation is the major complication of this procedure, which can be sutured locally or treated by reverting to the original operative choice of an anterior resection. The hospital stay is only 3 days on average, which is much shorter than a trans abdominal resection[69]. The saving in bed costs more than offsets the initial outlay to purchase the reusable equipment. The advantages of TEMS are listed in Table 7.

Table 7 TEMS excision of benign and malignant lesions[68,69]

	Lev-Chelouche	Neary
Number	75	40
Mortality	1 (1.3%)	0 (0%)
Morbidity	10 (13%)	8 (20%)
Hospital stay (days)	2-13 (mean 5.5)	1-6 (mean 3.2)

TEMS will continue to play an increasing role in the management of rectal lesion s. It has the advantage of allowing precise surgery in the mid and upper rectum on both benign and early malignant lesions. Advanced cancers are still better de alt with by trans-abdominal resection, unless the patient is elderly or unfit for major surgery. In these two groups the risk of major surgery out weighs the benefits.

Radiofrequency ablation

Liver metastases ultimately develop in 50% of patients with colorectal cancer[76]. Surgical resection offers the only potential for cure and long term survival, with 5 year survival rates up to 46% after "curative surgery"[76,77]. However, less than 25% of patients with colorectal liver metastases are considered suitable for hepatic resection[78]. In those patients where their tumour load, tumour distribution or co-morbidity prevents attempte d curative resection or they have recurrent disease, there are other therapeutic options. Palliation can be achieved with systemic or hepatic arterial chemotherapy, cryotherapy, and radioactive yttrium-90 microspheres, although cure is ext remely unlikely[79]. The mean survival of patients undergoing the different treatments for CRC liver metastases is listed in Table 8.

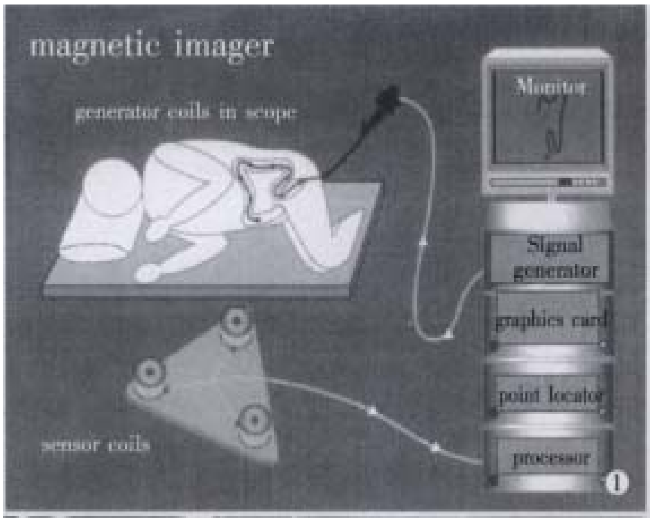
Table 8 Median Survival following treatment for CRC liver metastases

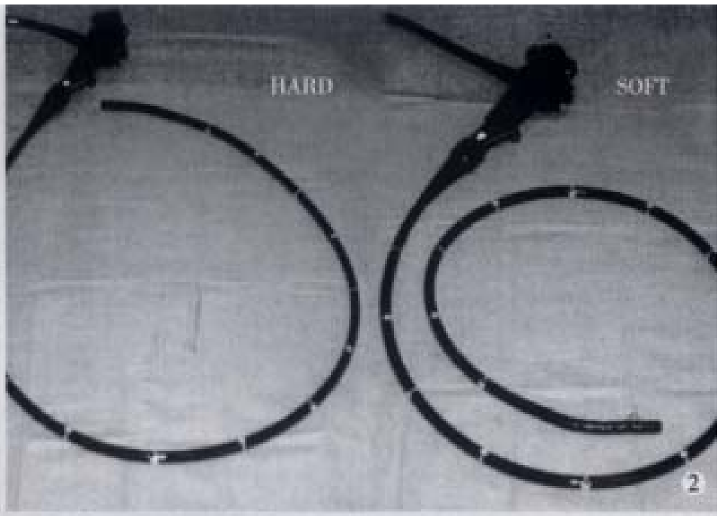
Treatment	Median survival
Supportive care[91]	7-11 months
IV Fluoruoracil chemotherapy[91]	11-14 months
Hepatic artery chemotherapy[91]	15-17 months
Radiofrequency ablation[84]	27 months

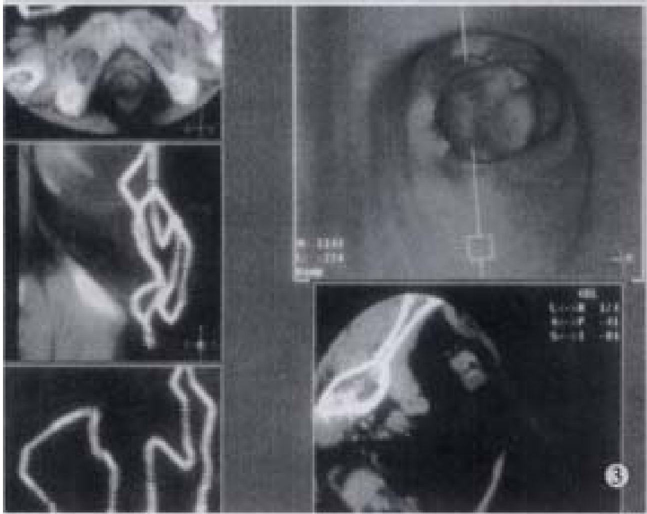
Radiofrequency ablation (RFA) by applying an alternating current at 300-500 kHz causes frictional heating of tissues to between 50-85 degrees Celsius. This thermal injury results in coagulative necrosis of spheres of tissue usually between 3 cm-5 cm in diameter[80,81]. It is safe and effective, with up to 98% of lesions showing persistent complete necrosis at 15 months[82-84]. Gillams[84] has shown RFA improves survival of patients with CRC liver metastases unsuitable for resection. RFA was performed in 69 patients, with an average number of metastases of 2.9 (range 1-16) and a mean maximum diameter of 3.9 cm (range 1-8). 26% had undergone previous hepatic resection and 93% received chemotherapy. The 3 year survival rate and mean survival time from diagnosis was 34% and 27 months respectively. 58% developed new hepatic metastases and 33% new extrahepatic disease. A subgroup of 24 patients, with less than 4 metastases, with a maximum diameter of 5cm, performed better, with a median survival of 33 months. Bilchik[85] recommends RFA for un-resectable primary or secondary malignant liver lesions up to 3 cm in size. Mortality and major morbidity occurred in 1.4% and 3.2% respectively, the latter being needle tract seeding. Minor morbidity, including pain and sepsis, occurred in 12%. RFA has the advantages of being safe, well tolerated and can be applied percutaneously, laparoscopically or at laparotomy. Lesions close to the diaphragm and colon are best accessed under direct vision by either of the latter 2 approaches. Percutaneous application has the added advantage of a shorter hospital stay of less than 24 hours. The role of RFA should continue to expand, as it is beginning to be applied to small lesions in the remaining liver segments during resection. In turn, this will broaden the horizon of hepatic resection.

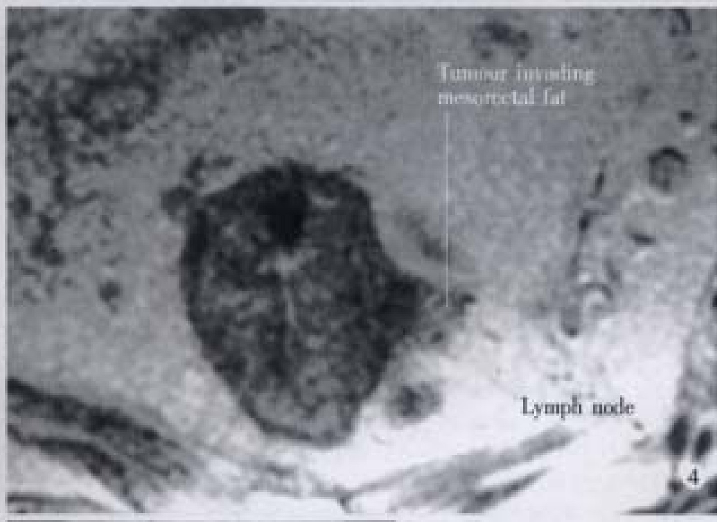
Robotics

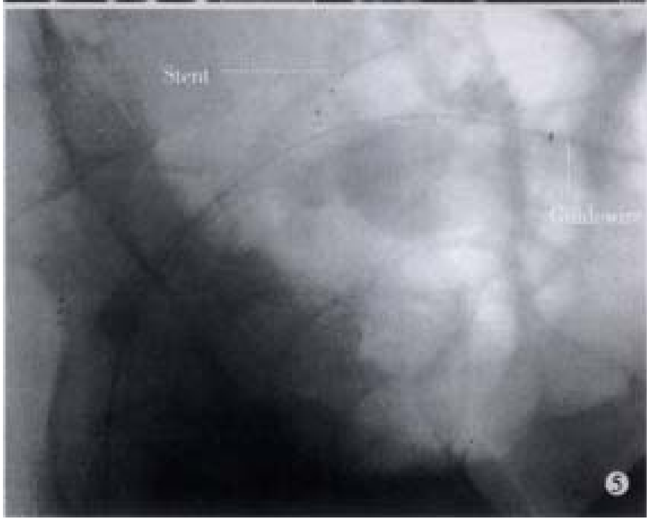
Robotics is at the forefront of the technological advances in medicine. Many innovations are being developed to aid laparoscopic surgery. Robotic arms has enabled solo laparoscopic surgery, which abolishes the need for an assistant, has greater stability of views and does not fatigue[86]. Voice activated robotic arms are being produced, which further enhances their ease of use. One of the drawbacks of laparoscopic surgery is the lack of depth perception. Robots (Davinci from Intuitive Surgical Ltd) and stereoscopic glasses (Optimize Interna tional) are being developed with 3-dimensional tactile and visual capabilities. Computer assisted colonoscopy, using a miniature self propelled robotic probe, is being developed to reduce the discomfort and increase patient acceptance of colonoscopy[87]. Tele-medicine will have an increasing role as we shift to digital data based investigations. Expert opinions can be given over the telephone, thus improving patient care.











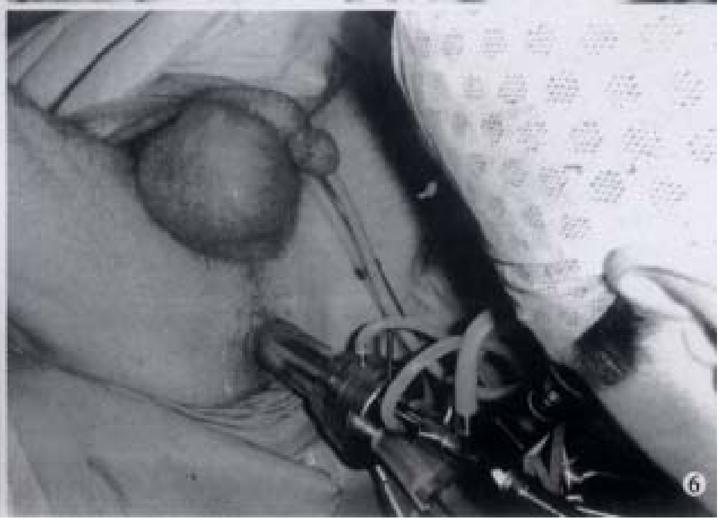


Figure 1 Magnetic imager colonoscope: magnetic generator coils built into the endoscope enable its position and presence of looping in the colon to be identified on the monitor.

Figure 2 Variable stiffness colonoscope: illustrating the stiff (hard) and flexible (soft) modes of the endoscope.

Figure 3 Virtual colonoscopy workstation interface (Marconi). T he operator is able to assess the 3-D data set simultaneously in 3 orthogonal planes. The upper right hand image demonstrates the endoluminal viewpoint and shows a 3cm polypoidal malignancy at the splenic flexure.

Figure 4 Thin cut imaging of a rectal carcinoma perpendicular to the long axis of the tumour displays the tumour breaching the muscularis propr ia and an enlarged lymph node within the mesorectum. Suggested staging T3N1.

Figure 5 Lateral view demonstrating a metallic stent (Boston Sc ientific, Watertown, MA) being deployed across a rectosigmoid carcinoma with the aid of a guidewire. The patient achieved prompt and effective decompression.

Figure 6 Trans-anal endoscopic microsurgery: 50 mm rectos cope is inserted through the anus. An attached stereoscopic binocular viewing eyepiece allows six-fold magnification of the operative field. Constant flow insufflation with carbon dioxide keeps the rectum dilated.

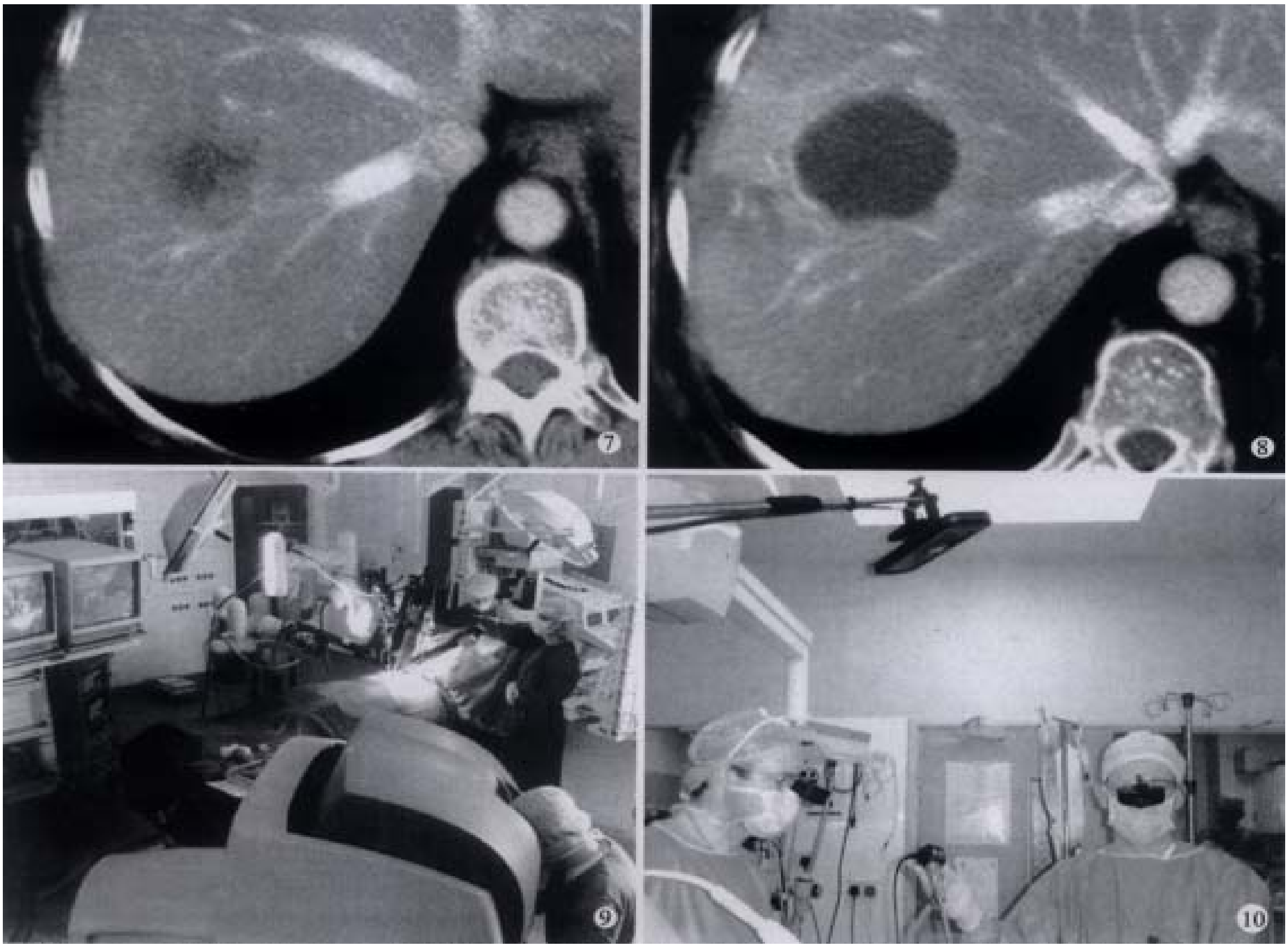


Figure 7 Radiofrequency ablation: CT scan demonstrates A 3.5 cm solitary colorectal metastasis in segment 8 of the right lobe of the liver.
Figure 8 Radiofrequency ablation: the post treatment CT scan sh ows a 4.5cm necrotic RFA lesion at the site of the previous tumour (Figur e 7). There is typical marginal enhancement and some perfusional anomalies in the subtended liver.
Figure 9 "Davinci": Operating robot (Intuitive Surgical Ltd).
Figure 10 Stereoscopic 3-D projection laparoscopic glasses (Optimize International).

OUTCOME OF COLORECTAL CANCER

Artificial neural networks

Analysis of the treatments available to patients with CRC traditionally relied on population statistics. These predictions have little meaning for individual patients. Artificial neural networks (ANN) are particularly suited for the analysis of complex databases and the relations within these data sets[88]. They allow recognition of patterns in complex biological data sets, which cannot be detected in conventional linear statistical analysis. The advant age of ANN's is that once the network is established, it can be used to predict outcome for individual patients. Imputation of data is the first step in setting up and training a network, and the more data entered the better. Outcome is entered at the same time. Once the network is validated using a second set of data and outcome, data from an individual can be entered and a prediction of outcome for that individual calculated.

Neural networks have been applied to several aspects of CRC. Bottaci[89] analysed pre operative, operative and follow up data on 334 patients treated for CRC. ANN's were used to predict the death of an individual patient and compared to a surgeon's opinion. In the first institution where the initial data to train the network was collected, the network was marginally more accurate (80% *vs* 75%). When this ANN was used on data from a second institution, its accuracy increased to 90%, compared to the surgeon's prediction of death of 79%. Neural networks have also been used to accurately predict the lymph node status and tumour stage of a resected colonic malignancy, based on the patient's age and tumour biopsy grade and immunohistochemistry[90]. Data from 75 patients were used to train the network. The ANN correctly predicted the lymph node status of 20 of 24 test cases (sensitivity 85%, specificity 80%) and the tumour stage of 21 of 24 test cases (sensitivity 92%, specificity 82%). The application of neural networks in coloproctology is endless. Once a network is established from a data set, the outcome for each individual patient on any aspect of CRC can be predicted.

ACKNOWLEDGMENTS Thanks to Professor A. Darzi, St Mary 's Hospital, London and Dr. B. P. Saunders, St Mark's Hospital, Harrow for contributing Figures.

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Edited by Rampton DS and Ma JY