



# Improving paediatric interventional radiology services

An intercollegiate report

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# Foreword

It should not be acceptable for children to be treated by open surgery when they could undergo minimally invasive percutaneous image-guided therapy to achieve the same outcome. Yet this is precisely what happens in many centres treating children in the UK in 2010. The recent report on Birmingham Children's Hospital highlighted this but it is but one example. This joint report from The Royal College of Radiologists and the Royal College of Paediatrics and Child Health aims to improve this situation by examining the problem and suggesting solutions to improve service delivery and access to paediatric interventional radiology. We hope that in the current uncertain climate those who commission and provide paediatric services will take note.

Both Colleges would like to thank Dr Derek Roebuck for chairing and authoring the report and the efforts of his committee all of whom contributed significantly. They are listed at the end of the document.

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# 1. Introduction

Paediatric interventional radiology (PIR) encompasses a range of minimally invasive procedures which are performed using image guidance; procedures may be for diagnostic or treatment purposes. Within the field of paediatrics, PIR has an increasingly significant role to play in the delivery of safe and effective care by reducing risks, decreasing length of stay and lowering costs.<sup>1,2</sup> It is, therefore, critical that there is consideration of the current provision of PIR and a vision developed for how it could be delivered in the future to ensure consistent access and quality.

The purpose of this work was:

- To review the current provision of paediatric interventional radiological procedures in UK hospitals
- To review the scope and delivery of paediatric interventional radiological procedures in UK hospitals of different types and sizes
- To identify where problems lie in service provision and delivery
- To recommend models of service delivery.

This document intends to provide clinicians, managers and commissioners with an overview of how PIR services can be delivered to ensure high-quality services for children and young people in the UK.

The working party canvassed opinions on the current and potential future provision of PIR services in the UK. Methods included announcements at the annual meetings of the British Association of Paediatric Surgeons and British Society of Paediatric Radiology, an item in the e-newsletter of the Children's Surgical Forum of the Royal College of Surgeons and an email to all members of the British Society of Interventional Radiology.

## 2. Current provision of paediatric interventional radiology (PIR)

The current PIR activity in the UK is unknown, partly because existing coding arrangements often do not discriminate between PIR procedures and their surgical alternatives, and partly because the data is not easily extracted from radiology department information systems. However, the PIR service at one large children's hospital performed more than 2,600 procedures (in 2,100 patient episodes) in 2009.

Techniques performed by interventional radiologists include central venous access, gastrointestinal intervention (such as gastrostomy and oesophageal dilatation), aspiration or drainage of fluid collections including nephrostomy, angiography including arterial embolisation and the treatment of vascular malformations. Appendix 1 provides more explanation of the more common PIR procedures and Appendix 2 outlines a classification of PIR based on the utility or necessity of image guidance.

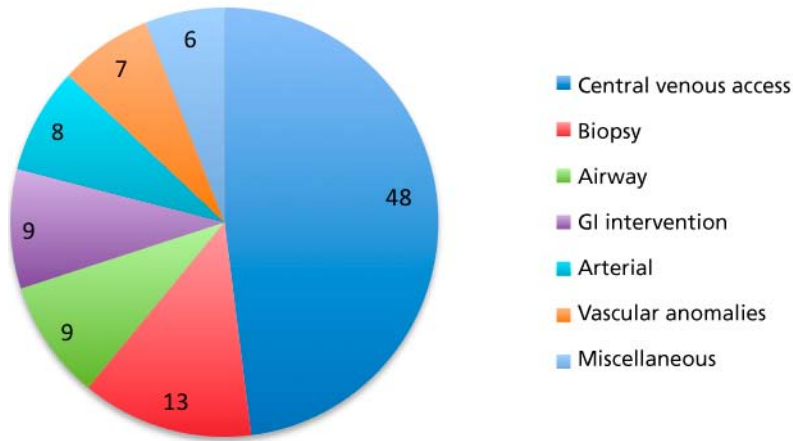
Paediatric interventionists are currently drawn from several disciplines.

- In many hospitals, adult interventional radiologists provide services. Their skills and equipment are often limited, and referral rates for complex procedures in very sick children are high.
- Interventional radiologists with a special interest in paediatric intervention are less common as training opportunities are very limited.
- Diagnostic paediatric radiologists with a special interest in intervention sometimes provide a limited service.
- Paediatric surgeons or paediatricians occasionally provide image-guided interventions and often do so successfully in a limited way. They generally have little or no formal training in image-guided procedures, image interpretation, or catheter and guidewire skills.
- Nurses and radiographers can successfully perform many delegated procedures as part of a PIR team.

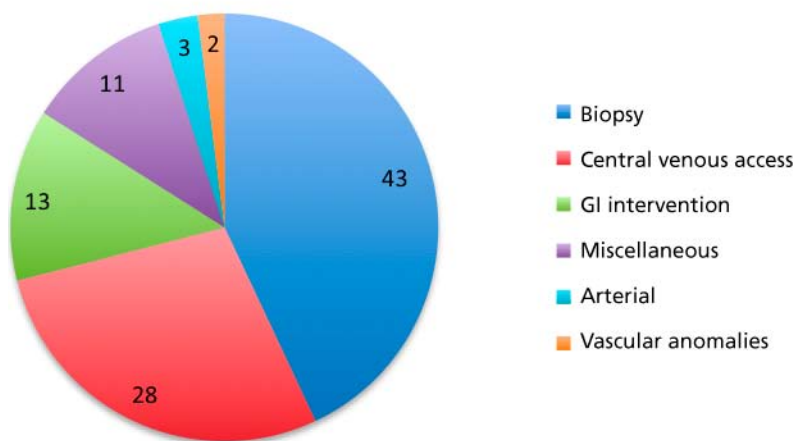
The key issues around who undertakes PIR relate to skills and equipment. Services which are staffed by interventional radiologists with paediatric training are likely to be able to undertake most procedures and will also have access to paediatric appropriate equipment. Adult interventionalists, diagnostic radiologists and other non-interventional radiology (IR) healthcare professionals have high referral rates to PIR specialists, partly due to more limited skills and competencies but also due to lack of appropriate equipment. Figure 1 (opposite) outlines the variation in the number and type of interventions in three different services.

**Figure 1. PIR procedure types (%) at three UK trusts**

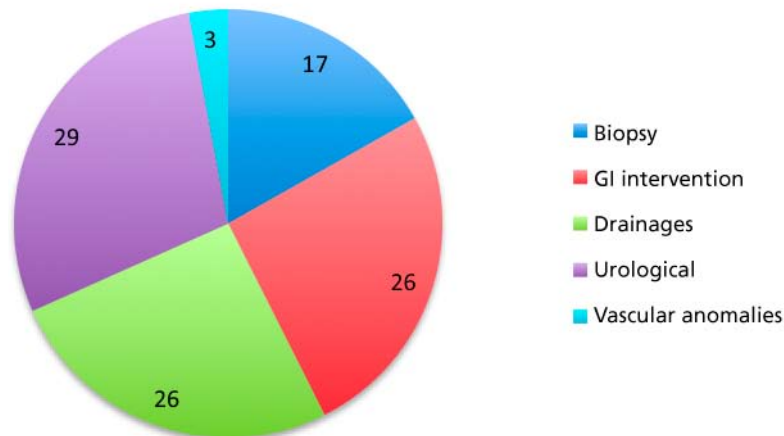
Service A employs two full-time paediatric interventional radiologists and a half-time interventional neuroradiologist, who in total performed about 2,500 procedures in 2008.



Service B employs one paediatric interventional radiologist (who also has sessions in diagnostic radiology), who performed about 200 procedures in 2008



Service C employs one paediatric radiologist, who undertakes about 100 PIR procedures per year



## 3. Current issues

PIR services in the UK currently face a number of difficulties, which undermine the ability of healthcare professionals to deliver high-quality care.

### 3.1 Inconsistent provision and capacity

Currently, there is inconsistent provision of PIR across the UK. The level of PIR service can vary considerably, even between dedicated children's hospitals. Some specialist paediatric centres can provide high-quality care and, as a consequence, referral rates are high to these centres. For some cases this is clinically appropriate, however, there are many interventional procedures which can be safely delivered on a local or regional basis if skills and equipment are available. Many families are forced to travel long distances due to the inconsistency of provision.

*'We provide simple PIR services for children who have been referred from hospitals hundreds of kilometres away. This is poor planning – every hospital that looks after children should have a system in place to provide these common procedures, either locally or at a regional centre. If they can't organise this properly they shouldn't be providing paediatric services at all.'*

The variability in provision causes considerable capacity issues for those services that do offer comprehensive PIR. Services have not been commissioned to reflect referrals received and, consequently, capacity is often inadequate. Many hospitals struggle to provide continuity of service as they employ few interventionalists. A strategic approach is required to ensure that specialist centres can provide PIR for complex cases with clear and consistent referral processes.

### 3.2 Training and maintaining competences

Historically, PIR has been performed by interventional radiologists (and interventional neuroradiologists) with a special interest in paediatrics, or paediatric radiologists with an interest in intervention.<sup>3</sup> They have usually undergone five years of radiology training, with specialisation in years 4 and 5. About half of all current practitioners have also undertaken an additional Fellowship year. As there are currently no formally accredited training positions in PIR outside the United States and Canada, it is difficult for a radiologist in the UK to obtain appropriate training in PIR. Furthermore, if a trainee does go abroad, they may not return to the UK once their training is complete.

Due to the problems of provision, capacity and support for PIR, there are challenges in terms of recruiting trainees, who perceive PIR as a lifestyle-limiting option with limited career potential.

Training in low-volume, high-complexity procedures such as arterial interventions will continue to be a problem in PIR. In some countries, there has been a trend towards the concentration of such procedures in a few major centres, which might ameliorate this problem.<sup>4</sup> All paediatric interventional radiologists will, however, need some exposure to such techniques and it will, therefore, be necessary for training programmes to allow rotation of trainees to other centres to ensure complete training.

Most PIR procedures involve a set of core skills: access to the appropriate site under image guidance (often using a needle and/or catheter and guidewire) followed by some type of intervention (such as biopsy, embolisation or balloon dilatation). This concept emphasises the transferability of skills between different body systems and also explains why PIR has made an impact on practice in so many areas of hospital paediatrics. This transferability of skills helps the interventionist with a relatively low caseload maintain his or her competence. Specialists in certain other paediatric disciplines, including general surgery, urology and cardiology, may also use image guidance to perform various procedures. This results in an overlapping pattern of provision of some procedures; for example, angiography and gastrostomy. Although this encourages transfer of skills and ideas, it does make it more difficult to maintain competence for any group of individuals by spreading a small caseload among a number of specialties. Furthermore, it is recognised that the requirement for paediatric intervention in non-specialist paediatric centres may be relatively low, especially if paediatric intervention is spread across disciplines.

*'I am an interventional radiologist at an acute hospital which services about 350,000 people. I have done nothing paediatric in the last ten months other than a Hickman [central venous] line in a 14-month-old child. I am happy to help where I feel able but the cases are few and far between; the vast majority go to a regional children's hospital and my prior training was predominantly adult IR. With the paucity of cases I imagine that I will become more reluctant to take on anything more than vascular access work in the small kids.'*

### 3.3 Out-of-hours provision

The majority of radiology departments report either no interventional on-call rota, or informal arrangements without adequate resources.<sup>5</sup> This problem is much more obvious in PIR, where there are currently no hospitals with sufficient consultant staff to maintain an on-call rota.

*'The adult radiologists won't do anything paediatric out of hours so the three of us informally agree to come in if we are available, ie, if they can get hold of one of us, which they usually can ... The paediatric surgeons are still not happy with this and want a 24/7 rota – which is impossible with our staffing levels. We would need three more to have a rota and there simply isn't enough work for that many at the moment.'*

### 3.4 Lack of recognition of paediatric interventional radiology (PIR)

The advantages of image-guided minimally invasive techniques are well known. However, these benefits have not been fully realised, with many children not receiving PIR, even where national guidelines, such as guidance from the National Institute for Health and Clinical Excellence (NICE), exist.<sup>6</sup> There is a lack of recognition at several levels: within radiology departments, by other specialties and by trust management. Such a lack of recognition is



concerning, as collaboration is key to successful outcomes within PIR. Perhaps the best example of interdisciplinary collaboration in PIR is the management of children with vascular malformations, which in most large centres is carried out by teams including radiologists, dermatologists, pathologists, various types of surgeon and other healthcare professionals.<sup>7,8</sup>

PIR has developed relatively quickly and has challenged existing approaches of care, but given the clear benefits in terms of clinical outcome and speed of recovery, it seems illogical for PIR not to be fully supported throughout the NHS.

*'Failure of clinicians, especially surgeons, to recognise the safety, scope and types of image-guided procedures in children.'*

*'No flexibility in the job plan to do these procedures – I am rota'ed for diagnostic paediatric radiology throughout the week and have to catch up with routine departmental work after hours or [at] weekends.'*

The deskilling of diagnostic paediatric radiologists in PIR is an almost universal trend. The support of radiology departments for the development of PIR services, and the consultants who provide these services, appears to vary widely between children's hospitals.

*'There is a decrease in the number of paediatric diagnostic radiologists prepared to undertake even the simpler cases, presumably because of small numbers limiting skills and the fear of criticism or litigation if something goes wrong when working at the margins of one's competence.'*

### 3.5 Inadequate facilities and equipment

A common issue is lack of adequate facilities and equipment to undertake PIR. Procedures that were once performed at the bedside under local anaesthesia – for example, renal biopsies or insertion of temporary haemodialysis catheters – have now become image-guided interventions, often performed under general anaesthesia. These developments have occurred in a haphazard manner, without formal planning, driven to some extent by changes in the role of junior doctors and partly by the perceived advantages of image guidance for simple procedures. This lack of planning explains to a degree why the provision of appropriate facilities has lagged so far behind the demand. Lack of support by hospital management also appears to be a problem in some centres.

*'I have an interest in vascular malformations. My adult patients get treated very promptly. My children don't. That is because... the children's hospital does not have adequate [angiographic] facilities for me to undertake this work.'*

Furthermore, because patients from a few hundred grams to over 100 kg may undergo interventional procedures in a children's service, any PIR service requires a range of

equipment of all sizes. Currently, the lack of appropriate equipment may limit which procedures a service is able to undertake.

A broader issue is that in some cases, devices may have to be used 'off label' as no appropriate devices are available for paediatric applications. In other circumstances, 'adult' devices can be used for different indications in children. For example, adult coronary angioplasty balloons and stents can be used in the renal arteries of children, which are often of a similar size to adult coronary arteries. There are some applications, however, for which no ideal device currently exists for small children. Collaboration between professional bodies and industry may improve this problem in the future.

### **3.6 Interdependency with anaesthetics**

To undertake PIR, there needs to be the availability of appropriately skilled anaesthetists. This is currently a significant problem for many PIR services, where often PIR is forced to take place on an ad hoc basis or out of hours. This is unsustainable for radiologists and unfair for patients and their families.

*'The vast majority of my work is ad hoc, on emergency lists and out of hours.'*

# 4. Improving paediatric interventional radiology (PIR) services

## 4.1 Requirements of a successful paediatric interventional radiology (PIR) service

To provide a consistent, high-quality service requires a strategic approach to service delivery, using appropriate models of care which can be delivered across the UK. It also requires healthcare professionals with the right skills and competences to deliver care. In particular, training programmes need to be developed to provide interventionists, who may specialise in PIR, in interventional radiology with a special interest in paediatrics, or in paediatric radiology with a special interest in PIR.

Any service must be able to provide:

- Sufficient radiologist capacity to provide a timely and sustainable PIR service
- Sufficient nurses and radiographers to support PIR procedures. In larger centres, specialist PIR nurses and radiographers contribute significantly to the safety and efficiency of the service. A play specialist may be helpful to support children undergoing PIR procedures. All of these healthcare professionals will require appropriate training and support
- Appropriate anaesthetic cover to support the sedation and general anaesthesia for invasive procedures
- Safe and sustainable out-of-hours cover, whether delivered on a regional, networked basis or by individual services. Given the relatively small numbers of cases involved, it is likely to involve discussion about alternative patient pathways when a PIR service is not available – for example, default to surgical treatment – and also document an area of possible need for service development<sup>5</sup>
- Facilities designed to meet the need of PIR procedures, with paediatric appropriate equipment.

### 4.1.1 Training in paediatric interventional radiology (PIR)

Developing effective models of specialist training will be crucial to the future of PIR. All individuals working in PIR must have undergone appropriate training. This is most simply achieved through a period of training in radiology to a Certificate of Completion of Training (CCT) followed by a Fellowship in PIR. As part of supporting PIR training, a UK-based fellowship needs to be developed.

Adult interventional radiologists who do part-time or occasional work in children's hospitals will need to ensure they have training in child protection and child communication skills. They may have to spend some time with an experienced paediatric interventional radiologist to gain initial experience and will need to ensure that their skills are maintained.

When non-radiologists wish to perform PIR procedures, they will need a period of training which will vary according to what procedures they are to perform and their existing discipline. If these procedures involve the use of ionising radiation, they will need to show that they have undertaken appropriate accredited training in radiation protection, preferably with special emphasis on the requirements in children.

## 4.2 Potential models of provision of paediatric interventional radiology (PIR)

The most appropriate model of service delivery will vary for each organisation, depending on the volume of cases and the availability of skills and facilities. It is crucial that there is a strategic approach to ensure that there is coherent provision at a regional level, which balances the needs of patients with the critical mass and facilities required. Even in hospitals with a similar size and nature of work, different solutions may emerge. Each hospital should adopt the most appropriate model for its own circumstances.

### 4.2.1 Small and medium general hospitals

These are unlikely to have sufficient volume to justify a PIR service. Children requiring PIR should be referred elsewhere. There should be clarity about patient pathways and access to services within a reasonable distance for the more common PIR procedures.

### 4.2.2 Regional children's hospitals

There are several possible models to choose from.

*General paediatric radiologists provide a PIR service*

General paediatric radiologists (perhaps ~3) can develop and maintain the skills required to cover the majority of PIR, with complex cases referred elsewhere. It is unlikely that there will be sufficient staff to provide 24-hour cover, and therefore referral to specialist centres may be required out of hours. Clarity around complex and out-of-hours care will be required. There is a risk that general paediatric radiologists may become deskilled in PIR, thus making this approach difficult to sustain.

*Paediatric surgeons or anaesthetists may provide certain PIR procedures, often with the support of diagnostic radiologists*

A limited range of PIR procedures (almost exclusively central venous access) can be provided by non-radiologists. For everything else, patients are either referred out or undergo open surgery rather than minimally invasive IR procedures. This arrangement deals effectively with certain common procedures, such as central venous access, but does not provide any sophisticated PIR cover and in isolation is inadequate to cover all eventualities. In addition, it undermines the principle that PIR is the most appropriate procedure for certain cases.

*Adult interventional radiologists may provide PIR services*

For some services, adult interventional radiologists providing PIR services may be the most appropriate model for the delivery of PIR. It may be that the relatively small size of some children's hospitals means that a dedicated PIR service run by consultant paediatric radiologists cannot be achieved in the near future. The advantages of this system include the potential for comprehensive cover of all procedures which are also performed in adults, often by subspecialists in the field. In addition, a 24-hour service can be maintained if it is practical to include the children's hospital in the local network for interventional cover.

However, adult interventional radiologists may not be familiar with the subtleties of paediatric practice and will need to develop close working relationships with paediatricians. This may be hampered if their job plans do not allocate enough time in the children's hospital, such as to attend multidisciplinary team meetings. Other requirements include child protection and other relevant paediatric training.

### 4.2.3 Specialist children's hospitals

A dedicated PIR service providing all procedures is most likely to be developed in larger children's hospitals. Specialist paediatric interventional radiologists would perform all PIR, with or without input from diagnostic paediatric radiology. These services are likely to consist of at least three dedicated radiologists, with support from interventional neuroradiologists. There remains the challenge of providing out-of-hours care with this number of staff. This model requires a relatively high volume of cases, probably achieved by paediatric interventional radiologists undertaking vascular and enteric access procedures.

In certain highly specialised areas of PIR, national commissioning may be appropriate. This has already occurred in airway intervention, with National Commissioning Group funding of the National Service for Severe Tracheal Disease in Children at Great Ormond Street Hospital in London. Other areas could be considered, including treatment of renovascular hypertension, but this would require support from all relevant national professional bodies.

### 4.2.4 More than one system may apply in the same hospital

It is possible for several different models of care to coexist within the same setting; for example, with particular procedures being undertaken by paediatric radiologists, with cover provided by adult interventionalists. This does, however, limit the potential for the hospital to be a referral centre.

*'All ... drainages and biopsies are performed by one of two paediatric radiologists either in theatre or our intervention suite. Access to these services tends to be easy ... In our absence we tend to delegate to one of our colleagues, usually an 'adult' interventional radiologist if appropriate. The hepatobiliary intervention is managed by two predominantly 'adult' interventionalists and again access to these services is easy. We do not offer a central venous access service as this is dealt with by the [paediatric] surgeons and we do not have the capacity to deal with this workload.'*

## 5. Recommendations

1. Children should not be denied the benefits of minimally invasive PIR procedures. It follows that all children's hospitals should have a clear policy for PIR. This may involve the provision of services locally by a combination of paediatric radiologists, properly supported 'adult' interventional radiologists and in some cases non-radiologists. Unambiguous arrangements must be in place for the early referral of children with problems requiring PIR services that the hospital cannot provide in a timely fashion. (Action: NHS trusts)
2. Some hospitals have paediatric services that are too small to justify any provision of PIR. Children in these hospitals who require or may require PIR should be identified and referred to a centre where PIR is available 24/7. There must be clarity about these arrangements and recognised arrangements in place between hospital trusts. Each hospital should have a policy to ensure that appropriate diagnostic imaging and other services are always available to allow this to occur in a timely fashion. (Action: NHS trusts, commissioners)
3. All children's hospitals providing PIR services should ensure that appropriate facilities (usually one or more angiographic suites [or operating theatres or fluoroscopy rooms with suitable imaging equipment], anaesthetic and recovery areas, storage rooms and offices) are available to support the local demand for PIR services. (Action: NHS trusts, strategic health authorities [SHAs], commissioners)
4. Every hospital must have a strategy to deal with out-of-hours emergencies requiring PIR. (Action: NHS trusts, SHAs)
5. All children's hospitals providing PIR services should ensure that appropriate anaesthetic resources (including dedicated general anaesthetic lists) are available to support the local demand for PIR. (Action: NHS trusts, the Royal College of Anaesthetists, commissioners)
6. All PIR services must be supported by an adequate number of appropriately trained and paid nursing, radiographic and administrative staff. (Action: NHS trusts, SHAs, commissioners)
7. Certain PIR procedures are so specialised (or require such complex interdisciplinary support) that they should be performed only in large children's hospitals under appropriate commissioning arrangements. (Action: NHS trusts, SHAs, commissioners)
8. With thoughtful planning (including appropriate paediatric training and support as noted above), adult interventional radiologists can perform PIR procedures, either in adult or children's hospitals. These adult IRs may provide a range of procedures in hospitals with no dedicated PIR service, improve the availability and continuity of the existing PIR service and/or support paediatric radiologists when low-volume, high-complexity procedures are performed. (Action: NHS trusts, SHAs, The Royal College of Radiologists)
9. Many PIR procedures can be performed by appropriately trained non-radiologists. This may require initial training and review by radiologists, and would therefore be an appropriate topic for future intercollegiate collaboration. Where this is thought appropriate consideration must be given to maintenance of competence. In centres with a smaller PIR workload, joint working may be a solution. (Action: The Royal College of Radiologists, the Royal College of Paediatrics and Child Health, the Royal College of Surgeons, the Royal College of Anaesthetists)

10. Training of paediatric interventional radiologists in years 5 or 6 should be a high priority. At least one and preferably two one-year training positions should be offered annually in appropriate departments for this purpose. The Deaneries should be consulted regarding this. (Action: [The Royal College of Radiologists](#), [deaneries](#), [General Medical Council](#))
11. Dedicated posts as consultant paediatric interventional radiologists should be created. (Action: [NHS trusts](#), [SHAs](#), [commissioners](#))
12. Consideration by The Royal College of Radiologists and the General Medical Council should be given to creating recognised subspecialties in paediatric radiology and interventional radiology. Interventional radiology is now a recognised subspecialty by the General Medical Council as of Spring 2010. (Action: [The Royal College of Radiologists](#), [General Medical Council](#))
13. Investment should be made into researching and developing paediatrically appropriate equipment to support PIR. (Action: [Government](#), [Medical Research Council](#))

# Appendix 1. Common paediatric interventional radiology (PIR) procedures

## Central venous access

Although the use of image guidance is clearly advantageous for 'difficult' central venous access,<sup>9</sup> there is increasing recognition that PIR techniques should be used in all elective procedures. Various techniques have been described, most based on ultrasound-guided venous puncture and fluoroscopic guidance for catheter placement.<sup>10,11</sup> PIR is also involved in the management of the complications of central venous access.<sup>11,12</sup>

## Gastrointestinal (GI) intervention

The major GI procedures performed in PIR are oesophageal dilatation, gastrostomy (and procedures based on gastrostomy such as insertion of transgastric jejunal tubes) and caecostomy.<sup>13</sup>

Oesophageal dilatation has been performed by radiologists for over 25 years.<sup>14</sup> The use of balloon catheters and fluoroscopy is not only probably safer than bougienage, but allows the use of innovative techniques in difficult cases.<sup>15</sup> Endoscopy is mostly unnecessary unless visual inspection of the oesophageal mucosa and/or biopsy is required, but is a useful adjunct for some difficult procedures.

Image-guided gastrostomy may be performed by either an antegrade or a retrograde technique.<sup>13,16,17</sup> In the antegrade technique, percutaneous fluoroscopic puncture of the inflated stomach precedes the passage of a flanged gastrostomy tube down the oesophagus and out through the abdominal wall. The retrograde technique can be used to insert one of a range of tubes (balloon-retained tubes or buttons, or pigtail catheters) directly through the anterior abdominal wall and into the stomach. Either approach can be converted for transgastric jejunal access.

Percutaneous caecostomy is an effective technique in the treatment of faecal incontinence in children.<sup>18–20</sup>

## Biopsy

Though a diagnostic rather than therapeutic procedure, biopsies of the major solid abdominal organs (liver, kidneys and spleen) are invasive and almost always best achieved using an ultrasound-guided percutaneous technique. Various different techniques are available for biopsy of extraneural tumours, but image-guided percutaneous needle biopsy<sup>21</sup> is gaining in popularity, and in many centres is used for most such tumours.

## Aspiration and drainage of fluid collections

In the abdomen, the most common fluid collections requiring percutaneous aspiration and/or drainage are appendiceal and other abscesses<sup>22,23</sup> and cerebrospinal fluid collections in children with ventriculoperitoneal shunts.<sup>24</sup> Image-guided techniques are now widely preferred over open (surgical) drainage or 'blind' drain insertion in this context.

In the thorax, both lung abscess and empyema can be treated by PIR techniques.<sup>25</sup> Insertion of a small pigtail catheter with instillation of a fibrinolytic agent is probably a better treatment for empyema than thoracoscopy.<sup>25,26</sup>

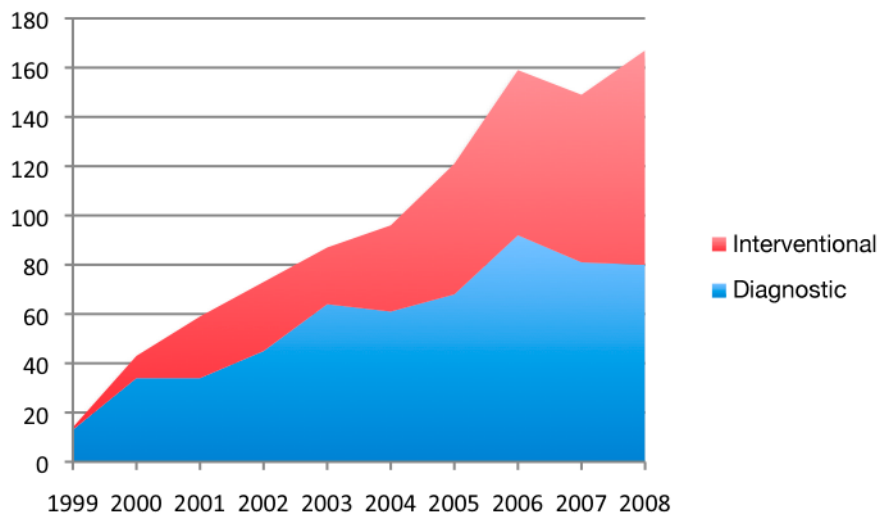


## Angiography and arterial intervention

The rapid improvement in non-invasive scanning technology might have been expected to have decreased the need for paediatric catheter angiography, but that does not appear to have been the case in many centres, where there has been a consistent rise in activity (Figure 2). This is partly because of the increasing use in children of various interventional techniques based on angiography (arteriography), including angioplasty and stenting,<sup>27,28</sup> embolisation<sup>29–31</sup> and regional chemotherapy.<sup>32–34</sup>

### Figure 2. Growth in angiographic activity at Great Ormond Street Hospital

There has been consistent growth in angiographic activity (as measured by the number of arterial PIR procedures per year) at Great Ormond Street Hospital (London) since 1999, when a permanent PIR service was established



## Nephrostomy and urological intervention

Most interventions in the urinary tract are based on image-guided nephrostomy.

Various methods of performing paediatric nephrostomy have been described.<sup>35,36</sup> Other PIR techniques in the urinary tract include ureteric dilatation and stenting,<sup>36</sup> percutaneous nephrolithotomy<sup>36–38</sup> and percutaneous balloon pyeloplasty.<sup>39,40</sup>

## Airway intervention

The most common PIR techniques used in the airway are balloon dilatation and stent insertion.<sup>41–43</sup> Endoscopic assistance is probably more important in the airway than in the oesophagus.

## Treatment of vascular malformations

PIR has played a crucial role in recent advances in the diagnosis and treatment of vascular malformations.<sup>8</sup> Sclerotherapy, usually by image-guided percutaneous injection, is the main form of treatment for children with venous<sup>8,44</sup> and cystic lymphatic<sup>45,46</sup> malformations. There is some evidence that the long-term outcome for patients with venous malformations is better if they are treated in childhood, and by specialists in this field.<sup>47</sup> Arteriovenous malformations can be treated by transarterial, direct percutaneous and/or retrograde transvenous embolisation techniques. Children with these conditions are best managed by an interdisciplinary team.<sup>7,8,44</sup>

## Appendix 2. Classification of paediatric interventional radiology (PIR) procedures according to need for image guidance

(See also Appendix 1)

Procedures requiring image guidance (almost always performed by PIR)	Procedures where image guidance is probably superior to other techniques  (usually performed by PIR)	Procedures where image guidance is a reasonable alternative to other techniques  (performed by PIR & other disciplines)	Procedures which do not require image guidance but are sometimes performed by PIR
Angiography and arterial interventions like embolisation for trauma, GI haemorrhage or arteriovenous malformations (AVM)	Oesophageal dilatation  (when endoscopy is not needed for other reasons)	Gastrostomy	Removal of central venous catheters and port devices
Arterial angioplasty and/or stenting for arterial occlusions and damage	Oesophageal stenting	Insertion of peritoneovenous shunts	Other biopsies (eg, skin or muscle biopsy)
Selective venous sampling	Airway dilatation and stenting	Paracentesis and thoracentesis	Change of gastrostomy buttons
Local thrombolysis	Percutaneous biopsy of liver or kidney	Percutaneous biopsy of lymph nodes	
Recanalisation of occluded veins	Routine central venous access		
Venous angioplasty and/or stenting	Sclerotherapy of cystic lymphatic malformations		
Difficult central venous access	Drainage of thoracic and abdominal abscesses		
Sclerotherapy of venous malformations			
Radiofrequency ablation			
Percutaneous cholangiography and biliary intervention			
Percutaneous cholangiography and biliary intervention			
Percutaneous biopsy of focal lesions in internal organs			
Nephrostomy			

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Approved by the Board of the Faculty of Clinical Radiology of The Royal College of Radiologists : 25 June 2010

Approved by the Royal College of Paediatrics and Child Health: 16 June 2010

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