Familial adenomatous polyposis (FAP) is one of two well described forms of hereditary colorectal cancer. The primary cause of death from this syndrome is colorectal cancer which inevitably develops usually by the fifth decade of life. Screening by genetic testing and endoscopy in concert with prophylactic surgery has significantly improved the overall survival of FAP patients. However, less well appreciated by medical providers is the second leading cause of death in FAP, duodenal adenocarcinoma. This review will discuss the clinicopathological features, management, and prevention of duodenal neoplasia in patients with familial adenomatous polyposis.

FAMILIAL ADENOMATOUS POLYPOSIS

FAP is an autosomal dominant disorder caused by a germline mutation in the adenomatous polyposis coli (APC) gene. FAP is characterised by the development of multiple (> 100) adenomas in the colorectum. Colorectal polyposis develops by age 15 years in 50% and age 35 years in 95% of patients. The lifetime risk of colorectal carcinoma is virtually 100% if patients are not treated by colectomy.

Patients with FAP can also develop a wide variety of extraintestinal findings. These include cutaneous lesions (lipomas, fibromas, and sebaceous and epidermoid cysts), desmoid tumours, osteomas, occult radio-opaque jaw lesions, dental abnormalities, congenital hypertrophy of the retinal pigment epithelium, and nasopharyngeal angiofibroma. In addition, FAP patients are at increased risk for several malignancies, such as hepatoblastoma, pancreatic, thyroid, biliary-tree, and brain tumours.

Other gastrointestinal manifestations commonly found in FAP patients are duodenal adenomas, and gastric fundic gland and adenomatous polyps. Of concern, duodenal cancer is the second leading cause of death after colorectal cancer in these individuals.

EPIDEMIOLOGY OF DUODENAL POLYPS AND CANCER

After the colorectum, the duodenum is the second most commonly affected site of polyp development in FAP (fig 1). Duodenal adenomas can be found in 30–70% of FAP patients and the lifetime risk of these lesions approaches 100%.

Duodenal/periampullary adenocarcinoma is the leading cause of death in FAP after colorectal cancer. These patients have a 100–330-fold higher risk of duodenal cancer compared with the general population. Of note, duodenal cancer is rare in the population, with an incidence of 0.01–0.04%. Estimates of the cumulative risk of developing duodenal cancer in FAP range from 4% at age 70 years to 10% at age 60 years. Recently, a large prospective five nation study set the cumulative incidence rate of duodenal cancer at 4.5% by age 57 years. The median age of duodenal cancer development was 52 years (range 26–58).

UPPER GASTROINTESTINAL POLYP DISTRIBUTION AND TYPE

Polyps can be found throughout the duodenum, but the second and third portion and the periampullary region are the most commonly affected sites. This pattern probably reflects exposure of duodenal mucosa to bile acids, suggesting a role for these compounds in duodenal carcinogenesis. Most polyps in the duodenum are adenomas whereas polyps in the stomach are usually benign non-adenomatous fundic gland lesions. However, approximately 10% of gastric polyps are adenomas. Interestingly, Japanese and Korean FAP patients have a 3–4 times higher risk of gastric cancer compared with the general population whereas no increased risk has been found in Western countries. Besides polypoid neoplasia, flat adenomas can be found in the duodenum of approximately 30% of FAP patients and careful follow up of these lesions is recommended.

GENOTYPE-PHENOTYPE CORRELATION IN DUODENAL POLYPOSIS

The cause of FAP is germline mutation of the APC gene. The APC gene is a tumour suppressor gene with 15 exons that encodes a 2843 amino acid protein with a molecular weight of 309 kDa. One third of all germline mutations occur in codons 1061 and 1309.
Several genotype-phenotype correlations for colonic polyposis in FAP have been established. Mutations between codon 1250 and codon 1464 are associated with profuse polyposis (>5000 colorectal polyps) and those in codon 1309 with early onset of adenoma development (10 years earlier) and colorectal cancer (age <35 years).\textsuperscript{7,8} Mutations at the 5' and 3' extremes of the \textit{APC} gene cause attenuated FAP, characterised by oligopolyposis (less than 100 colorectal polyps) at presentation and later onset of colorectal cancer development (age >50 years).\textsuperscript{1}

The relationship between severity of duodenal polyposis and mutations in the \textit{APC} gene is less well understood. Taken together, published reports are inconsistent (table 1). One study failed to detect a correlation between the site of mutation and the severity of duodenal polyposis.\textsuperscript{17} In another, severe duodenal polyposis was found in patients with 5' mutations.\textsuperscript{9} Still others correlate severe duodenal disease with mutations in the central part of the gene.\textsuperscript{20} However, most reports indicate that mutations in exon 15 of the \textit{APC} gene, particularly distal to codon 1400, give rise to a severe duodenal phenotype.\textsuperscript{11,18,21-27}

**UPPER GASTROINTESTINAL ADENOMA-CARCINOMA SEQUENCE**

The adenoma-carcinoma sequence describes colorectal carcinogenesis as a stepwise progression of normal intestinal mucosa to aberrant crypt foci, adenoma, and finally invasive adenocarcinoma (fig 3). Activation of the Wnt signalling pathway, by biallelic inactivating \textit{APC} mutation or an activating \textit{\beta}-catenin mutation, can be regarded as the initiating step. Subsequent mutations in tumour suppressor genes (for example, \textit{p53} and \textit{SMAD4}) and oncogenes (for example, \textit{K-Ras}) lead to neoplastic progression of the adenoma-carcinoma sequence.\textsuperscript{28} Also, expression of important cell regulatory proteins is changed. One of these is cyclooxygenase-2 (COX-2), which is increasingly expressed in consecutive stages of the adenoma-carcinoma sequence.\textsuperscript{29,30}

The adenoma-carcinoma sequence, first identified for colorectal tumorigenesis, has been observed in the setting of duodenal carcinogenesis in patients with both FAP and sporadic disease. Spigelman and colleagues\textsuperscript{31} found a strong association between duodenal adenomas and duodenal cancer, showing that villous histology, moderate or severe dysplasia, and the presence of stage IV duodenal polyps were associated with malignant change. Also, case reports of duodenal carcinoma development in or near adenomas have been described.\textsuperscript{32,33} Moreover, Kashiwagi \textit{et al} noted \textit{p53} overexpression in 25% of tubular, 72% of tubulovillous/villous adenomas, and 100% of duodenal carcinomas,\textsuperscript{34} and \textit{K-Ras} codon 12 mutations have been detected in duodenal adenomas and carcinomas.\textsuperscript{35} In addition, \textit{SMAD4} mutations play a role in polydevelopment in the upper intestine in mice.\textsuperscript{36} Lastly, Resnick and colleagues\textsuperscript{37} demonstrated that transforming growth factor \textalpha (TGF-\textalpha) expression was greater in duodenal carcinomas than in adenomas, and that epidermal growth factor receptor (EGF-R) expression correlated with the degree of dysplasia in duodenal adenomas. These studies reveal that additional molecular alterations drive the transition of adenoma into carcinoma.

COX-2 is known to be an important mediator of colorectal neoplasia progression but expression of COX-2 has not been extensively studied in duodenal or upper gastrointestinal adenomas. Shirvani and colleagues\textsuperscript{38} found constitutive COX-2 expression in normal duodenum and oesophagus and significantly higher levels in oesophageal dysplastic tissues. Furthermore, these investigators showed that COX-2 expression in Barrett's oesophagus increased in response to pulses of acid or bile salts. COX-2 expression is also elevated in gastric cancers.\textsuperscript{39}

**CLASSIFICATION OF DUODENAL POLYPOSIS**

The most useful system for rating the severity of duodenal polyposis was developed by Spigelman and colleagues. This classification describes five (0–IV) stages. Points are accumulated for number, size, histology, and severity of dysplasia of polyps (table 2). Stage I indicates mild disease whereas stages III–IV imply severe duodenal polyposis (fig 4).\textsuperscript{32} Approximately 70–80% of FAP patients have stage II or stage III duodenal disease, and 20–30% have stage I or stage IV disease.\textsuperscript{40} The estimated cumulative incidence of stage IV duodenal disease however is 50% at age 70 years.\textsuperscript{4}\textsuperscript{51}

\begin{table}
\centering
\begin{tabular}{l|c|c|c|c|c|c|c|c|c|c}
\hline
5' & \textbf{Exons} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
\hline
\textbf{Condon} & 1061 & 1309 & 3' \\
\hline
\textbf{Condon} & 0 & 200 & 400 & 600 & 800 & 2843 \\
\hline
\end{tabular}
\caption{Classification of duodenal polyposis.}
\end{table}

**Figure 1** Polyps in the second part of the duodenum in a patient with familial adenomatous polyposis.

**Figure 2** Schematic representation of the adenomatous polyposis coli (\textit{APC}) gene, consisting of 15 exons and 2843 codons. One third of all germline mutations occur in codons 1061 and 1309. Mutations at the extremes of the \textit{APC} gene present as attenuated familial adenomatous polyposis.
Several investigators have shown that duodenal polyposis slowly progresses. One study followed 114 FAP patients for 51 months and found progression of polyps in size (26%), number (32%), and histology (11%). When individuals are followed for longer, duodenal polyps advance in Spigelman stage. Heiskanen and colleagues reported worsening polyposis in 73% of 71 FAP patients followed for 11 years. The median interval for progression by one stage was 4–11 years. Another group reported a stage change in 42% of patients with an average time of evolution by one stage of 3.9 years. Also, the risk of developing stage III or IV disease exponentially increases after age 40 years. The Spigelman classification also correlates with risk of duodenal malignancy. Stages II, III, and IV disease are associated with a 2.3%, 2.4%, and 36% risk of duodenal cancer, respectively.

**MANAGEMENT**

**Surveillance**

As noted, duodenal polyposis is ingravescent over time. Consequently, surveillance of the upper gastrointestinal tract for the development of neoplasia by end and side viewing scopes is recommended by most authorities. One long term upper tract surveillance study of 114 FAP patients failed to prevent the development of duodenal adenocarcinoma in six patients. These findings emphasise the need to adjust the frequency of surveillance and to entertain surgical treatment with increasing severity of disease. Recommendations concerning the age of initiation of upper tract surveillance are not uniform. Some propose that screening for upper gastrointestinal disease should start at the time of FAP diagnosis. The NCCN (National Comprehensive Cancer Network), after review of all case reports of duodenal cancer in FAP patients, recommended a baseline upper gastrointestinal endoscopic examination at 25–30 years of age. Guidelines for continued endoscopic surveillance after baseline examination have been developed according to Spigelman stage by several authorities. In general, recommendations include stage 0 every 4 years; stage I every 2–3 years; stage II every 2–3 years; stage III every 6–12 months with consideration for surgery; and stage IV strongly consider surgery (table 3).

**Endoscopic treatment**

Endoscopic treatment options for duodenal lesions include snare excision, thermal ablation, argon plasma coagulation,

### Table 1 Genotype-phenotype correlations for upper gastrointestinal polyposis in familial adenomatous polyposis (FAP)

<table>
<thead>
<tr>
<th>Author</th>
<th>No of FAP patients</th>
<th>Findings</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groves</td>
<td>129 patients</td>
<td>245 patients underwent upper GI endoscopy, 129 had known germline mutations. Mutations after codon 1400 tend to give rise to more severe duodenal polyposis</td>
<td>Exon 15 (distal)</td>
</tr>
<tr>
<td>Attard</td>
<td>15 patients</td>
<td>24 paediatric patients from 21 families underwent upper GI endoscopy. 15 patients had known APC mutation. Patients with upper GI adenomas were more likely to have mutations between codons 1225 and 1694.</td>
<td>Exon 15 (distal)</td>
</tr>
<tr>
<td>Matsumoto</td>
<td>4 members of 1 family</td>
<td>4 patients from 1 family with severe duodenal adenomatosis and a frame shift mutation in codon 1556</td>
<td>Exon 15 (distal)</td>
</tr>
<tr>
<td>Leggett</td>
<td>2 members of 1 family</td>
<td>2 members of 1 family with sparse colonic but severe upper GI adenomatosis and a 2 bp deletion in codon 1520</td>
<td>Exon 15 (distal)</td>
</tr>
<tr>
<td>Trimbath</td>
<td>1 (AFAP)</td>
<td>AFAP patient presenting with ampullary adenocarcinoma and distal resection</td>
<td>Exon 15</td>
</tr>
<tr>
<td>Bjork</td>
<td>15 patients</td>
<td>19 patients with stage IV duodenal adenomatosis or carcinoma. 15 APC mutations were detected, 12 were downstream of codon 1051 in exon 15.</td>
<td>Exon 15</td>
</tr>
<tr>
<td>Bertario</td>
<td>399 patients</td>
<td>Mutations between codons 976 and 1067 were associated with 3-4 fold increase in risk of duodenal adenomas</td>
<td>Exon 15 (proximal)</td>
</tr>
<tr>
<td>Emano</td>
<td>62 patients</td>
<td>Patients with germline mutations between codons 564 and 1465 have higher frequencies of upper GI adenomas than patients with a mutation between codons 157 and 416.</td>
<td>Exon 10–15</td>
</tr>
<tr>
<td>Matsumoto</td>
<td>34 patients</td>
<td>Patients with distal (exon 10–15) APC mutations have higher prevalence of duodenal adenomas than patients with proximal (exon 1–9) mutations</td>
<td>Exon 10–15</td>
</tr>
<tr>
<td>Saurin</td>
<td>33 patients</td>
<td>Mutation in central part (279–1309), risk factor for development of severe duodenal adenomatosis</td>
<td>Codon 279–1309</td>
</tr>
<tr>
<td>Soravia</td>
<td>7 AFAP kindreds</td>
<td>Kindreds with 5’ end mutations (exon 4 and 5) have more duodenal adenomas than kindreds with mutations in exon 9 and 3’ distal end</td>
<td>Codon 4 and 5</td>
</tr>
<tr>
<td>Friedl</td>
<td>86 patients</td>
<td>134 patients from 125 families had duodenal adenomas. From 86 patients the germline mutation was known. No correlation between site of mutation and duodenal adenomatosis</td>
<td>No correlation</td>
</tr>
</tbody>
</table>

*APC*, adenomatous polyposis coli; *COX*, cyclooxygenase; *AFAP*, attenuated familial adenomatous polyposis.

**Figure 3** The adenoma-carcinoma sequence. Activation of the Wnt signalling pathway, by an inactivating adenomatous polyposis coli (APC) mutation or an activating β-catenin mutation, is regarded as the first step in the adenoma-carcinoma sequence. Then, additional mutations in oncogenes (for example, K-Ras) and tumour suppressor genes (for example, p53 and SMAD4) drive further progression of the adenoma-carcinoma sequence. *COX*-2, cyclooxygenase 2.
and photodynamic therapy (PDT). Most reports of endoscopic therapy use snare excision. However, duodenal adenomas are often flat non-polypoid structures and, therefore, difficult to remove using conventional snare excision. For these cases, prior submucosal saline/adrenaline infusion may facilitate removal and reduce the risk of haemorrhage and perforation.\textsuperscript{40} In addition, thermal ablation,\textsuperscript{44, 46} argon plasma coagulation,\textsuperscript{47} or PDT\textsuperscript{48–51} may be suitable.

PDT is a non-thermal technique relying on the combined effect of a low power activating light and a photosensitising drug that is selectively retained within neoplastic tissue with minimal retention in surrounding normal tissue. Few reports of PDT for adenomas in the gastrointestinal tract exist. Loh and colleagues\textsuperscript{50} successfully applied PDT for resection of colorectal adenomas: 7/9 treated adenomas were eradicated. Others have used PDT for resection of neoplastic lesions in the upper gastrointestinal tract but results are disappointing (table 4).\textsuperscript{48, 49, 51}

Endoscopic treatment of duodenal neoplasia for Spigelman stage II and III polyposis has been pursued by some investigators. However, the benefit of this approach in eradicating duodenal polyposis is difficult to justify but may be useful in individual cases. Literature reports of endoscopic treatment for FAP patients with duodenal/ampullary polyps are summarised in table 4. These publications reveal that endoscopic treatment is usually insufficient to guarantee a polyp-free duodenum and fraught with complications. Recurrence rates of adenomatous tissue in duodenum of FAP patients treated endoscopically range from 50% to 100%.\textsuperscript{44, 46, 52, 53} Lower recurrence was reported by Norton and colleagues\textsuperscript{54, 55} but their study population also included patients with sporadic duodenal lesions.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Spigelman classification for duodenal polyposis in familial adenomatous polyposis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion</td>
<td>Points</td>
</tr>
<tr>
<td>Polyp number</td>
<td>1–4</td>
</tr>
<tr>
<td>Polyp size (mm)</td>
<td>1–4</td>
</tr>
<tr>
<td>Histology</td>
<td>Tubular</td>
</tr>
<tr>
<td>Dysplasia</td>
<td>Mild</td>
</tr>
<tr>
<td>Stage 0, 0 points; stage I, 1–4 points; stage II, 5–6 points; stage III, 7–8 points; stage IV, 9–12 points.</td>
<td></td>
</tr>
</tbody>
</table>

| Table 3 | Recommendations for management of duodenal polyposis in familial adenomatous polyposis, adjusted to the Spigelman stage of duodenal polyposis |
|---|---|---|---|
| Spigelman stage | Endoscopic frequency | Chemoprevention | Surgery |
| Stage 0 | 4 years | No | No |
| Stage I | 2–3 years | No | No |
| Stage II | 2–3 years | +/- | No |
| Stage III | 6–12 months | +/- | +/- |
| Stage IV | 6–12 months | +/- | Yes |

![Figure 4. Spigelman stages of duodenal polyposis. (A) Stage I. (B) Stage II. (C) Stage III. (D) Stage IV.](http://gut.bmj.com)
summary, endoscopic treatment appears useful in individual cases but follow up remains necessary and surgical intervention is often indicated in patients with more severe polyposis.

**Surgery**

Surgical options utilised to treat duodenal polyposis include local surgical treatment (duodenotomy with polypectomy and/or ampullectomy), pancreas and pylorus sparing duodenectomy, and pancreaticoduodenectomy. There are no randomised studies published to help guide surgical selection.

Publications of local surgical treatment with duodenotomy for duodenal polyposis in FAP patients are summarised in table 5. This surgery has proven insufficient to guarantee a polyp-free duodenum, with most studies reporting high recurrence rates in FAP patients with severe duodenal adenomatosis. Farnell and colleagues found a lower recurrence of duodenal polyps of 32% and 43% at five and 10 years of follow up, respectively. But this investigation also included sporadic duodenal polyposis cases and concludes that recurrence was higher in patients with a polyposis syndrome. Nevertheless, duodenotomy may be indicated in patients with one or two dominant worrisome duodenal lesions in otherwise uninvolved or minimally involved intestine. In the future, the postoperative use of chemopreventive medication may be a useful strategy.

More radical surgery, in the form of classical pancreaticoduodenectomy, or pylorus or pancreas preserving duodenectomy, has been indicated for patients with severe polyposis (stage IV), failed endoscopic or local surgical treatment, and carcinoma development. Others recommend consideration of surgery in patients with stage III polyposis. Low recurrence rates of polyposis have been reported with these procedures (table 6). The specific choice of procedure appears related to local expertise and the site of polyp involvement. Use of endoscopic retrograde cholangiopancreatography to evaluate biliary duct involvement in patients with ampullary lesions or those with laboratory test perturbations has been suggested to direct appropriate surgery. In the final analysis, the morbidity and mortality of these surgeries must be weighed against the risk of developing duodenal adenocarcinoma.

**Pharmacological treatment**

Non-steroidal anti-inflammatory drugs (NSAIDs) regress colorectal adenomas in FAP patients. The value of these agents for duodenal polyposis regression is unclear. Studies of duodenal adenoma regression have primarily utilised sulindac (NSAID) and selective COX-2 inhibitors (table 7).

Nugent and colleagues compared the effect of sulindac (n = 12) and placebo (n = 12) on the number of duodenal polyps. Polyp number decreased in four patients, increased in one, and was unchanged in five after six months of treatment with sulindac 400 mg/day. The difference between sulindac and placebo treated patients was not significant, possibly due to lack of statistical power. However, a second evaluation of endoscopic videotapes from this cohort revealed a statistically significant effect on small (≤2 mm) duodenal polyps whereas larger (>3 mm) duodenal polyps were unaffected. Another randomised crossover trial that compared sulindac...
Table 5  Local surgical treatment (duodenotomy with polypectomy and/or ampullectomy) for duodenal neoplastic lesions

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment</th>
<th>Follow up</th>
<th>Patients</th>
<th>Outcome</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soravia</td>
<td>Duodenotomy with polypectomy (1) or ampullectomy (4)</td>
<td>4–34 months (mean 18)</td>
<td>5 FAP</td>
<td>Recurrence in 4 patients. 1 patient died of cancer</td>
<td>1 transient duodenal fistula</td>
</tr>
<tr>
<td>Morpurgo</td>
<td>Transduodenal ampullectomy (1) or polyp excision (1)</td>
<td>6–24 months (mean 19)</td>
<td>2 FAP</td>
<td>Recurrence in 1 patient</td>
<td>1 severe pancreatitis</td>
</tr>
<tr>
<td>Alarcon</td>
<td>Local resection</td>
<td>8–33 months (mean 20.2)</td>
<td>5 FAP</td>
<td>Recurrence in 4 patients. 1 had progressive metastatic adenocarcinoma</td>
<td>NS</td>
</tr>
<tr>
<td>Heiskanen</td>
<td>Duodenotomy</td>
<td>0.4–15.1 years (median 6.8)</td>
<td>15 FAP</td>
<td>No significant difference in Spigelman stage preoperative and at latest endoscopy</td>
<td>No postoperative complications</td>
</tr>
<tr>
<td>Penna</td>
<td>Duodenotomy with polypectomy</td>
<td>5–36 months (mean 13.3)</td>
<td>12 FAP</td>
<td>Recurrence in 12 patients</td>
<td>NS</td>
</tr>
<tr>
<td>Penna</td>
<td>Duodenotomy with polypectomy</td>
<td>36–72 months (mean 53)</td>
<td>6 FAP</td>
<td>Recurrence in 6 patients</td>
<td>1 cholecystectomy for cholecystitis, 2 duodenal fistulas</td>
</tr>
<tr>
<td>de Vos tot</td>
<td>Duodenotomy with polypectomy</td>
<td>4–13 months (mean 11)</td>
<td>8 FAP</td>
<td>Recurrence in 6 patients</td>
<td>1 minor morbidity*</td>
</tr>
<tr>
<td>de Vos tot</td>
<td>Duodenotomy with polypectomy</td>
<td>5–103 months (mean 29)</td>
<td>22 FAP</td>
<td>Recurrence in 17 patients. 1 death from metastatic disease</td>
<td>1 minor morbidity*</td>
</tr>
<tr>
<td>Nederveen</td>
<td>Duodenotomy with polypectomy</td>
<td>35 months</td>
<td>1 FAP</td>
<td>Gastric cancer arising from a polyp at 35 months</td>
<td>No postoperative complications</td>
</tr>
<tr>
<td>Farnell</td>
<td>Transduodenal local excision</td>
<td>10 years</td>
<td>53 sporadic and FAP patients</td>
<td>Recurrence rate of 32% at 5 years and 43% at 10 years of follow up</td>
<td>3 pancreatitis, 3 leaks, 2 delayed gastric emptying, 2 ileus, 1 fluid overload</td>
</tr>
</tbody>
</table>

*That is, wound infection, atelectasis, or urinary tract infection.
NS, not stated; FAP, familial adenomatous polyposis.

Table 6  Pancreaticoduodenectomy and pylorus or pancreas preserving duodenectomy for duodenal neoplastic lesions

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment</th>
<th>Follow up</th>
<th>Patients</th>
<th>Outcome</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soravia</td>
<td>Pancreaticoduodenectomy</td>
<td>NS</td>
<td>1 FAP</td>
<td>Unknown</td>
<td>NS</td>
</tr>
<tr>
<td>Morpurgo</td>
<td>Pancreaticoduodenectomy</td>
<td>NS</td>
<td>4 FAP</td>
<td>No recurrence reported</td>
<td>Increased number of bowel movements. One patient required pouch excision and end ileostomy to control diarrhea. 3 patients experienced weight loss, 1 patients had episodes of pancreatitis</td>
</tr>
<tr>
<td>Alarcon</td>
<td>Pancreas sparing duodenectomy</td>
<td>40–50 months (mean 45.7)</td>
<td>3 FAP</td>
<td>No recurrence. Two of three patients had a small tubular adenoma in the duodenal bulb.</td>
<td>1 pancreatic fistula, 1 upper GI haemorrhage</td>
</tr>
<tr>
<td>Penna</td>
<td>Pancreaticoduodenectomy</td>
<td>9–108 months (mean 42)</td>
<td>7 FAP sever duodenal polyposis</td>
<td>1–9 years</td>
<td>1 duodenal cancer survived &gt;4 years</td>
</tr>
<tr>
<td>de Vos tot</td>
<td>Pancreaticoduodenectomy</td>
<td>7–96 months (mean 47)</td>
<td>23 FAP</td>
<td>Recurrence in 3, 6 died of metastatic disease</td>
<td>5 minor morbidity*, 12 major morbidity†, 1 patient died of postoperative complications</td>
</tr>
<tr>
<td>de Vos tot</td>
<td>Pancreas sparing duodenectomy</td>
<td>2–15 months (mean 11)</td>
<td>6 FAP</td>
<td>No recurrence</td>
<td>1 minor morbidity*, 3 major morbidity†</td>
</tr>
<tr>
<td>de Vos tot</td>
<td>Pylorus preserving duodenectomy</td>
<td>7–93 months (mean 45)</td>
<td>12 FAP</td>
<td>Recurrence in 3 of 9, 3 died of metastatic disease</td>
<td>1 minor morbidity*, 4 major morbidity†</td>
</tr>
<tr>
<td>Nederveen</td>
<td>Pancreaticoduodenectomy</td>
<td>37–162 months (mean 70.5)</td>
<td>7 FAP</td>
<td>1 patient developed jejunal adenomas 12 years after operation</td>
<td>1 patient developed pancreatic ascites</td>
</tr>
<tr>
<td>Chung</td>
<td>Pancreas sparing duodenectomy</td>
<td>0.5–3 years (mean 2.1)</td>
<td>4 FAP</td>
<td>No recurrence</td>
<td>1 gastric retention, 1 pancreatic fistula</td>
</tr>
<tr>
<td>Kalady</td>
<td>Pancreas sparing duodenectomy</td>
<td>10 years</td>
<td>3 FAP</td>
<td>1 had polyp recurrence in jejunum at 5 years of follow up</td>
<td>1 postoperative wound infection, 1 biliary leak</td>
</tr>
<tr>
<td>Ballard</td>
<td>(Pylorus preserving) pancreaticoduodenectomy</td>
<td>24 and 28 months 2 FAP</td>
<td>No recurrence</td>
<td>NS</td>
<td>11 leaks, 4 delayed gastric emptying, 1 delirium tremens, 3 abscesses. 1 patient died from bleeding and sepsis related to hepaticojejunostomy leak. Morbidity was higher after pancreas sparing duodenotomy.</td>
</tr>
<tr>
<td>Farnell</td>
<td>Pancreaticoduodenectomy</td>
<td>0.3–16 years (mean 5.6)</td>
<td>25 FAP and sporadic</td>
<td>No recurrences</td>
<td>10 leaks, 4 delayed gastric emptying, 1 delirium tremens, 3 abscesses. 1 patient died from bleeding and sepsis related to hepaticojejunostomy leak. Morbidity was higher after pancreas sparing duodenotomy.</td>
</tr>
</tbody>
</table>

*That is, wound infection, atelectasis, or anastomotic leakage, fistula formation, wound abscess, sepsis, or pancreatitis.
†That is, anastomotic leakage, fistula formation, wound abscess, sepsis, or pancreatitis.
NS, not stated; FAP, familial adenomatous polyposis.
300 mg/day with calcium and calciferol revealed no effect on duodenal polyps in 15 patients who completed six months of treatment with sulindac.66

Richard and colleagues67 treated eight FAP patients with residual small periampullary polyps with sulindac 300 mg/day for at least 10 months. Sulindac was discontinued in three patients due to side effects. Follow up endoscopy was performed every six months or at discontinuation of treatment. None of the patients showed regression of polyps; three patients developed large polyps and one an infiltrating carcinoma while on this drug.

A large randomised trial by Phillips and colleagues,64 with statistical power to detect small differences, investigated the effect of the specific COX-2 inhibitor celecoxib on duodenal polyp number and total polyp area. A 14% decrease in polyp number was found after six months of celecoxib 300–400 mg/day (n = 32) compared with placebo (n = 17) which was not statistically significant. Paired assessment of endoscopic videotapes, however, revealed a significant difference (p = 0.033), although no effect on polyp area was noted.

Windle and colleagues68 preformed a prospective, controlled, non-randomised phase II dose finding study for sulindac. These investigators compared effects of sulindac suppositories (n = 28) with placebo (n = 10) on rectal and upper gastrointestinal adenomas in patients that underwent colectomy. They found complete or partial reversion of rectal polyps but no effects on duodenal and papillary adenomas.

Preliminary data from a trial comparing another specific COX-2 inhibitor, rofecoxib 25 mg/day, with ursodeoxycholic acid (controls) for duodenal polyps showed a response in two of six patients on rofecoxib and in none of the controls (n = 6). Of note, both responsive patients had stage III disease whereas none of the patients with stage IV disease improved.73

A case report described that sulindac 300 mg/day prevented the recurrence of severe duodenal polyposis in a patient with FAP.73 Another described two patients in whom treatment with sulindac 300–400 mg/day normalised an adenomatous ampulla and eliminated moderate dysplasia.72 In contrast, Waddell and colleagues74 observed no effect of sulindac 300–400 mg/day on gastric and small intestinal polyps in two patients with FAP. In addition to chemoprevention with NSAIDs, H2 blockers have been studied. No significant difference was found in duodenal polyp number or adduct formation between the ranitidine and placebo groups.78

In conclusion, the results of NSAID and other compounds on regression or prevention of duodenal adenomas in FAP appear disappointing, although regression of small adenomas may occur.75

**Table 7** Familial adenomatous polyposis patients treated with sulindac, celecoxib, or refecoxib for duodenal adenomas

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment (dose/day)</th>
<th>Type of study</th>
<th>Duration</th>
<th>Patients</th>
<th>Outcome</th>
<th>Side effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nugent et al.64</td>
<td>Sulindac 400 mg</td>
<td>Randomised controlled clinical trial</td>
<td>6 months</td>
<td>11</td>
<td>Number of polyps ↓ in 5 patients (p = 0.12 vs placebo); Second evaluation: effect on small polyps (&lt; 2 mm) (p = 0.02)</td>
<td>1 patient with indigestion</td>
</tr>
<tr>
<td>Seow-Choen et al.64</td>
<td>Sulindac 300 mg</td>
<td>Randomised controlled clinical trial</td>
<td>6 months</td>
<td>15</td>
<td>No effect</td>
<td>No adverse events reported</td>
</tr>
<tr>
<td>Richard et al.65</td>
<td>Sulindac 300 mg</td>
<td>Clinical trial</td>
<td>10–24 months</td>
<td>5</td>
<td>No regression of small residual polyps; 3 patients developed large polyps; 1 breakthrough carcinoma</td>
<td>2 patients with abdominal cramp, 1 patient with upper GI bleeding</td>
</tr>
<tr>
<td>Phillips et al.64</td>
<td>Celecoxib 800 mg</td>
<td>Randomised controlled clinical trial</td>
<td>6 months</td>
<td>30</td>
<td>Number of polyps ↓ compared to placebo (p = 0.03)</td>
<td>1 patient with allergic reaction, 1 patient with symptoms of dyspepsia, 2 patients with mild gastritis due to NSAID</td>
</tr>
<tr>
<td>Winde et al.66</td>
<td>Sulindac 50–300 supp dose reduction</td>
<td>Prospective, controlled, non-randomised phase II dose finding study</td>
<td>Up to 4 years</td>
<td>xx</td>
<td>No effect on upper GI polyps</td>
<td></td>
</tr>
<tr>
<td>Maclean et al.70</td>
<td>Refecoxib 25 mg</td>
<td>Randomised controlled clinical trial</td>
<td>6 months</td>
<td>6</td>
<td>Improvement in 2 patients with stage III polyposis; no effect in 4 patients; no effect in ursodeoxycholic acid group</td>
<td></td>
</tr>
<tr>
<td>Parker et al.72</td>
<td>Sulindac 300 mg</td>
<td>Case report</td>
<td>5 and 14 years</td>
<td>2</td>
<td>Sulindac normalised adenomatous ampulla and eliminated moderate dysplasia</td>
<td>No recurrence of duodenal polyps</td>
</tr>
<tr>
<td>Theodore et al.72</td>
<td>Sulindac 300–400 mg</td>
<td>Case reports</td>
<td>4.5–5 years</td>
<td>2</td>
<td>No effect on gastric and small intestinal polyps</td>
<td></td>
</tr>
</tbody>
</table>

*The control group was treated with calcium and calciferol.  †The control group was treated with ursodeoxycholic acid. NSAID, non-steroidal anti-inflammatory drug.

**MOLECULAR MECHANISMS OF CHEMOPREVENTION WITH NSAIDS**

Studies of chemoprevention/regression of duodenal polyps in FAP have primarily utilised NSAIDs. The action of these agents has been divided into COX dependent, mediated through inhibition of the COX enzymes, and COX independent, caused by direct actions of NSAIDs on different molecular mechanisms.

**COX dependent mechanisms**

NSAIDs are best known for inhibitory effects on COX-1 and COX-2, key enzymes in the conversion of arachidonic acid to prostaglandins (PGs) (fig 5). COX-1 expression occurs in...
most tissues whereas COX-2 is expressed in response to growth factors, lipopolysaccharide, cytokines, mitogens, and tumour promoters. PGs are involved in cellular functions such as angiogenesis and cell proliferation. Therefore, inhibition of PG synthesis could explain part of the antineoplastic effects of NSAIDs. Also, COX-2 inhibition has antiangiogenic effects, as confirmed by several different studies. COX-2 inhibition may also induce apoptosis, mainly via inhibition of PGE2, and inhibit invasive properties of cancer cells. COX-2 was induced by coculture and promoted invasion in vitro that was inhibited by NSAIDs or RNAi against COX-2.

**COX independent mechanisms**

Several lines of evidence support the importance of COX independent means of action of NSAIDs. Firstly, high doses of NSAIDs induce apoptosis in COX-1 or COX-2 deficient cell lines and, secondly, PGs do not rescue these cells from apoptosis.

Various COX-2 independent targets for NSAIDs have been proposed (fig 6). β-Catenin appears to be an important target as both indomethacin and exisulind reduce β-catenin expression in colorectal cancer cells. Also, NSAIDs induce apoptosis via both the membrane bound and mitochondrial pathway. High doses of aspirin antagonise the transcription factor nuclear factor κB, which regulates expression of antiapoptotic genes encoding proteins such as TRAF, c-IAP, c-FLIP, Bcl-XL, and A1. Several studies indicate a role for proteins of the Bcl-2 family in the apoptotic response to NSAIDs, and the membrane death receptor apoptotic pathway may also be involved. Furthermore, TGF-β signalling is implicated in NSAID chemoprevention. NSAIDs affect cell adhesion and lipoxigenase metabolism, which reduce colorectal cancer cell invasion and could explain part of the apoptotic response to NSAIDs in colorectal cancer cells. Finally, it appears that members of the peroxisome proliferator activated receptor (PPAR) family, PPARδ and PPARγ, are directly targeted by NSAIDs and PGs.

**CONCLUSIONS AND FUTURE DIRECTIONS**

With improvement in the management of colorectal disease and increased life expectancy, duodenal polyposis and malignancy have emerged as major health problems in patients with FAP. Although most patients eventually develop duodenal polyps, these lesions occur at later age and have lower potential for malignant change compared with colonic polyps. Moreover, duodenal adenomas seem less responsive to chemoprevention with NSAIDs than colonic counterparts.

Currently, the main treatment options for duodenal polyposis are frequent surveillance and targeted endoscopic treatment, adjusted by severity of duodenal lesions. However, these modalities alone cannot guarantee a polyyp-free duodenum. In patients with severe disease, duodenotomy or duodenectomy may be necessary. Drug therapy of duodenal adenomas would be appropriate treatment but
most published reports find no significant effect of NSAIDs or COX-2 inhibitors on duodenal adenoma regression. Increasing insights into the molecular changes during the adenoma-carcinoma sequence in the duodenum may point to future treatment strategies. Duodenal mucosa is exposed to different environmental factors than that in the colon. Low pH and bile acids may affect control of growth and malignant potential of duodenal tumours.12 13 38 Little is known about the role of potential molecular targets for chemoprevention, including COX-2, PPARα, PPARγ, TGF-β receptor type II, EGF-R, and inducible nitric oxide synthase. More powerful chemopreventive/regressive regimens could result from combinations of NSAIDs or COX-2 inhibitors with other drugs, such as selective inhibitors of receptor tyrosine kinases or EGF-R. Further study is needed to understand the molecular changes in duodenal adenoma development and identify molecular targets for chemoprevention and regression of duodenal polyposis.

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