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MINIREVIEWS

How best to manage gastrointestinal stromal tumor

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Abstract

Gastrointestinal stromal tumors (GISTs) are rare but most common nonepithelial tumor of gastrointestinal tract. They are often found incidentally on computed tomography and endoscopic investigations. Increasing knowledge of the pathogenesis of GISTs and the advent of tyrosine kinase inhibitors revolutionized the management of GISTs. The newer advanced endoscopic techniques have challenged the conventional surgery although the true efficacy and safety of endoscopic approach is not clear at this time. This review article focuses on pathogenesis, diagnosis and management of GISTs.

Key words: Gastrointestinal stromal tumor; Endoscopy; Endoscopic ultrasound-fine-needle aspiration; Tyrosine kinase inhibitor; Imatinib

Core tip: Gastrointestinal stromal tumors (GISTs) are most common mesenchymal tumors in the gastrointestinal tract. The management of GISTs is revolutionized with the advent of tyrosine kinase inhibitors (TKIs) and newer advanced endoscopic techniques. Accurate identification and differentiation of GISTs from other submucosal tumors is achieved with the help of endoscopic ultrasound. The management of small to medium GISTs are feasible by newer advanced endoscopic and/or laparoscopic techniques. Team approach involving endoscopist, pathologist, radiologist, medical oncologist and surgeon is key in optimal management of GISTs. This article focuses on role of TKIs and endoscopist perspective in the management of GISTs.

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INTRODUCTION

Gastrointestinal stromal tumors (GISTs) are the most common mesenchymal (sub epithelial) tumor, and are

frequently found in stomach and small intestine[1]. GISTS are hypothesized to originate from interstitial cells of cajal (ICC) which coordinate gut motility[2]. GISTs are rarely found in the peritoneum, mesentery and omentum[3]. GISTs have varied malignant potential, with about 40% of GISTs that are localized at initial diagnosis give rise to metastasis[4], and about 10%-20% of GISTs present with distant metastasis[5,6]. In Europe, the annual incidence of GISTs is about 10 cases per million[7]. In the United States, the annual incidence of GIST ranges from 4000 to 6000 new cases per year (7-20 cases per million population per year)[8]. The mean age at diagnosis is 63 years[9]; men and women are equally affected. The majority of GISTs are sporadic and may be associated with mutations like NF1, C-kit, platelet derived growth factor receptor-alpha (PDGFRA), succinate dehydrogenase (SDH) and deletions in chromosome 1 involving SDH c[10].

PATHOGENESIS OF GIST

Overall, GISTs are defined by the presence of *KIT* gene or PDGFRA mutation. Majority (80%) of GISTs have *KIT* gene mutations and biologic response of KIT receptor is produced without a bound ligand[11]. KIT receptor tyrosine kinase activity in normal cells is regulated by binding of endogenous KIT ligand or stem cell factor (SCF)[12]. In the majority of cases, spontaneous receptor dimerization and activation occurs when exon 11 is affected by *KIT* gene mutation. However, in few cases, a different mechanism results in uncontrolled KIT signaling if mutation occurs in Exon 9, 13 or 17. In cases with NF1, uncontrolled KIT activation may be present even in the absence of *KIT* gene mutation (wild type)[13]. A subset of GISTs which are negative for *KIT* gene mutations are positive for receptor tyrosine kinase PDGFRA mutations. GISTs expressing PDGFRA or *KIT* gene mutations have similar biologic consequences[14]. About 10% of adult GISTs have neither KIT gene nor PDGFRA mutation[15]. SDH-ubiquinone complex 2 is composed of subunits A, B, C and D which is part of Krebs cycle and respiratory chain[16]. In mutant SDH, dysfunction of electron transport chain in mitochondria leads to defective oxidative phosphorylation, which ultimately leads to abnormal stabilization of hypoxia inducible factors (HIF)[17]. Carney-Stratakis syndrome is caused by germline mutation in SDH subunits B, C or D which leads to GIST and paraganglioma[18].

Histologically GISTs are subdivided in to spindle cell (60%-70%), epithelioid (30%-40%) or both (10%). GISTs with spindle cells are compact, highly cellular, arranged in fascicular or whorled pattern with minimal amount of stroma and contain eosinophilic, basophilic or amphophilic cytoplasm. Epithelioid tumors have abundant cytoplasm which is amphophilic to clear and cellular borders are clearly defined[19]. Antibodies to CD34 and CD117 appear in most GISTs[20]. CD34 is a transmembrane glycoprotein present on vascular endothelium and human hematopoietic progenitor cells[21]. CD34 is expressed in a wide variety of tumors and it is detected in about 50%-80% of GISTs[2,11,20]. CD 117 is expressed in 80%-100% of GISTs and it is not expressed in smooth muscle or neural tumors which helps in distinguishing GISTs from other gastrointestinal mesenchymal tumors[20] (Figure 1).

CLINICAL PRESENTATION AND DIAGNOSTIC TOOLS

Clinical manifestations of GISTs are highly variable and it depends on tumor size and location. GISTs are usually asymptomatic and found incidentally by imaging or endoscopy[22]. Symptoms include melena, hematemesis, abdominal pain, discomfort, fullness, early satiety and palpable mass. GISTs in proximal stomach can cause dysphagia and tumors in pylorus can present as gastric outlet obstruction[23]. Rectal GISTs can present with hematochezia[24]. Rarely, they can present as intraperitoneal rupture of large tumor causing hemoperitoneum[25]. GISTs can occur as part of a syndrome; Carneys triad (gastric GIST, pulmonary chondroma, paraganglioma)[26], or neurofibromatosis type1 (mostly spindle cell GIST)[27]. Overall, about 50% of GISTs have local or distant metastasis at the time of presentation[28], with the liver being the most frequent site of metastasis. Other common sites of metastasis include the bone, peritoneum, retroperitoneum, lung, pleura, and subcutaneous (scar) tissue[29].

Computed tomography (CT) is the primary modality of choice for diagnosing GISTs[30,31]. CT tumor characteristics such as size greater than 10 cm, calcifications, irregular margins, heterogeneous, lobulated, regional lymphadenopathy, ulceration, extraluminal and mesenteric fat infiltration are more likely to be associated with metastasis[29]. CT enterography uses large volumes of oral contrast and it is superior to conventional CT. It has advantage of displaying the entire thickness of the small bowel, better visualization of deep ileal loops without superimposition and evaluation of surrounding mesentery[32]. MRI is more accurate than CT for delineating rectal GISTs and in detecting liver metastasis, hemorrhage and necrosis[33].

Esophagogastroduodenoscopy (EGD) shows most sub epithelial lesions as a bulge with a smooth, intact, normal appearing mucosa in the gastrointestinal tract. Hwang *et al*[34] did a prospective study and patients were referred for endoscopic ultrasound (EUS) to evaluate sub epithelial masses diagnosed previously by EGD, sigmoidoscopy or colonoscopy. The size of the mass during endoscopic exam was measured by open biopsy forceps for size reference. Results showed endoscopy was 98% sensitive and 64% specific in identifying intramural lesions. Intramural size measurement of endoscopy correlated with EUS ($r = 0.88$, $P < 0.001$) but, for extramural lesions, it was suboptimal ($r = 0.56$)[34]. Overall, the study concluded endoscopy had a high sensitivity but low specificity in identifying the location of sub epithelial lesions and histologic confirmation by EUS-fine-needle aspiration (FNA) should be obtained for masses originating from 3rd (submucosa) and 4th layer

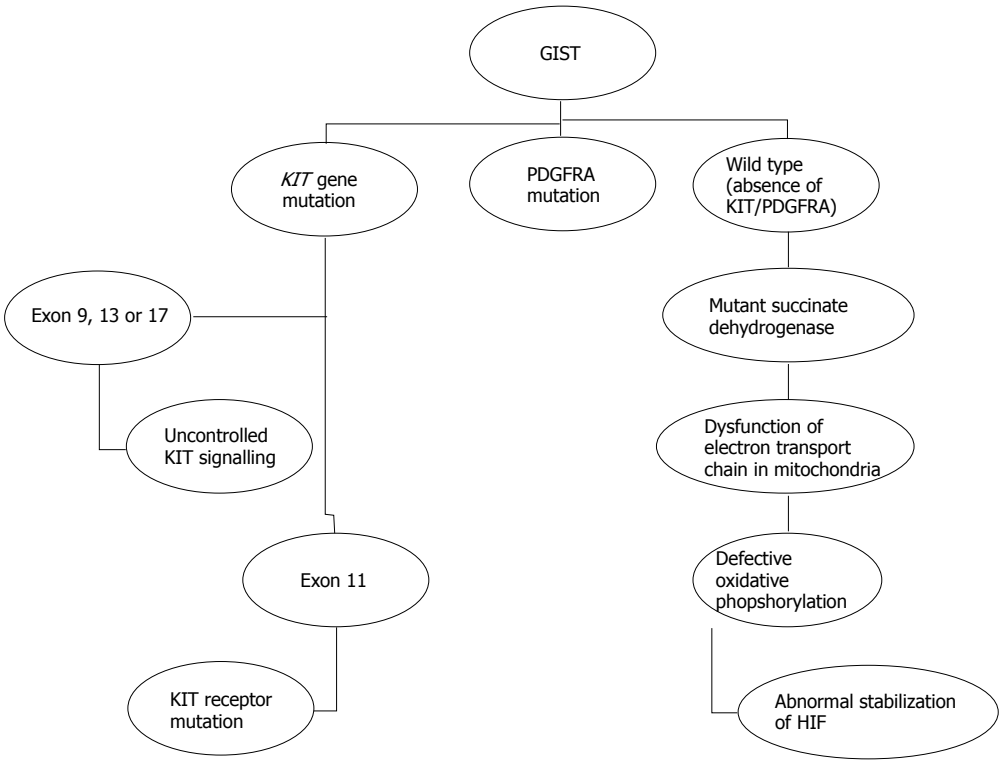

Figure 1 Pathogenesis. GIST: Gastrointestinal stromal tumor; PDGFRA: Platelet derived growth factor receptor-alpha; HIF: Hypoxia inducible factors.

(muscularis propria)[34].

Endosonographically GISTs appear as oval or hypoechoic mass arising from the muscularis propria. EUS features suggestive of malignancy include enlarged lymph nodes, size greater than 4 cm, irregular borders and cystic spaces with in the mass[35]. EUS has 92% sensitivity and 100% specificity in differentiating submucosal tumor from extrinsic compression[36]. Chen *et al*[37], retrospectively evaluated EUS characteristics to predict the malignant potential of GISTs. EUS features of GISTs were compared to National Institutes of Health (NIH) criteria for classification of malignant potential and were divided in to very low/low risk, intermediate/high risk. Results showed that GISTs at high risk for malignancy were associated with EUS characteristics like lesion size ($P < 0.0001$), cystic change ($P = 0.015$) and surface ulceration ($P = 0.036$)[37]. EUS-FNA cannot accurately differentiate benign from malignant GIST due to lack of mitotic activity on smears. The definitive method for assessment of GIST malignant potential requires surgical resection.

Dewitt *et al*[38] evaluated the diagnostic yield and complications of EUS-Trucut biopsy (EUS-TCB) for gastrointestinal mesenchymal tumor (GIMT). EUS-FNA was performed in 33/38 (87%), and was diagnostic on final cytology in 25/33 (76%) and by FNA-immunochemistry (FNA-IC) in 12/24 (50%). EUS-TCB obtained visible tissue specimen in 37/38 (97%), and diagnostic in the final TCB histology in 30/38 (79%) and TCB-IC in 30/31 (97%)[38]. Overall, the authors concluded that EUS-TCB should be considered as an alternative to EUS-FNA when technically feasible[38].

Na *et al*[39] evaluated the yield and utility of 19-gauge (G) TCB *vs* 22-G FNA for diagnosing gastric sub epithelial tumors (SETs). The diagnostic yield of TCB *vs* FNA were 77.8% *vs* 38.7% ($P < 0.0001$). The Accuracy of TCB *vs* FNA for diagnosing GISTs was 90.9% *vs* 68.8%; and for non-GIST SETs was 81.1% *vs* 14.3% respectively. There were 9 technical failures with TCB likely due to stiffness, poor maneuverability of the needle and location of the tumor[39]. The most common procedure associated adverse events were pain, hemorrhage (requiring endoscopic hemostasis) and fever[39]. Procedure related events in TCB *vs* FNA were [3/90 (3.3%) *vs* 5/62 (8.1%); $P = 0.27$] respectively[39].

Positron emission tomography (PET)-CT using ^{18}F-fluorodeoxy glucose (FDG) detects cancer based on changes in tissue metabolism[40,41]. PET-CT is used for initial staging and to monitor disease progression. A baseline ^{18} FDG-PET should be obtained before treatment so that the results can be used to compare with future studies[42]. Liver metastasis from GIST often appear as isodense lesions on CT, but may be detected by PET. Hence PET compliments CT in resolving ambiguity of liver lesions in patients with GISTs[42].

Gayed *et al*[43] showed that the sensitivity and positive predictive value of ^{18}F-FDG PET were 86% and 98% respectively and it is superior to CT in predicting early response to therapy in recurrent or metastatic GISTs[43]. Yoshikawa *et al*[40] evaluated the efficacy of PET-CT to predict the malignant potential of GIST. Standardized uptake value maximum (SUVmax) and GIST parameters

(Ki-67 labeling index and mitotic index) were compared. SUV max and Ki67 labeling index were significantly elevated in high risk group when compared to low/intermediate risk group[40]. Tumor response to treatment with imatinib mesylate may be detected by a decrease in CT attenuation units (Hounsfield units, HU)[44]. However, there may be delay in measurement of cellular and macroscopic changes after treatment with imatinib by CT. In contrast, PET using ^{18}F-FDG can detect early effects induced by imatinib and decrease in FDG uptake after the initiation of imatinib treatment indicates good prognosis[45].

The "Response Evaluation Criteria in Solid Tumors" (RECIST) classification was previously used, however, due to limitations in assessing malignant response to immunotherapy such as imatinib, RECIST has been replaced by the Choi criteria[46]. Limitations of RECIST were primarily because the response to therapy can occur not only in tumor size but also in structure like decreased tumor density and enhancement of intratumoral nodules[31,47]. The Choi criteria of contrast-enhanced CT is based on decrease in tumor size by 10% in any dimension or decrease in structure by 15%, and was found to be more predictive of time to tumor progression (TTP) than RECIST[48].

PROGNOSIS AND RISK STRATIFICATION

Mitotic index, tumor size, location (gastric *vs* non-gastric) and tumor rupture are independent risk factors for GIST metastases[4]. Joensuu *et al*[49] analyzed the association between KIT and PDGFRA mutation and RFS in GIST patients treated with surgery alone. The authors concluded that tumor mutation status should not be interpreted in isolation from other risk factors[49]. The American College of Surgeons Oncology trial (ACOSOG) Z90001 study found that tumor size, location and mitotic rate were important in RFS but not tumor mutation status[50]. Gold *et al*[51] developed a nomogram by calculating concordance probabilities and by comparing three commonly employed staging systems NIH-Miettinen[52], NIH-Fletcher[53] and Armed Forces Institute of Pathology (AFIP)-Miettinen[54]. The investigators concluded that the nomogram can accurately predict RFS after the resection of localized, primary GIST[51].

MANAGEMENT OF GIST

Surgery is the treatment of choice for primary and localized GISTs[55]. The goal of surgery is complete tumor resection (negative microscopic and macroscopic margins) with functional preservation (often accomplished by wedge resection), while avoiding tumor rupture and injury to the pseudo capsule[55]. McCarter *et al*[56] analyzed factors associated with R_0 (grossly and histologically negative margin), R_1 (grossly negative but histologically positive margins), R_2 resection (grossly positive margins) and assessed the risk of recurrence with and without imatinib[56]. Factors associated with R_1 resection included tumor size (> or = 10 cm), tumor rupture and location[56]. The authors concluded there was no significant difference in recurrence free survival (RFS) in patients who underwent R_1 *vs* R_0 resection of GIST with or without adjuvant imatinib[56]. Although the management of R1 resection after complete resection is not clear, options include careful observation (watchful waiting), re-excision and adjuvant imatinib treatment.

Laparoscopic wedge resection (LWR) is recommended for gastric GIST smaller than 5 cm. To prevent tumor seeding in laparoscopy, plastic bag is recommended to collect the tumor sample and direct handling of tumor with forceps is contraindicated. Wedge resection of gastric GIST is considered standard treatment[57] and lymphadenectomy is not indicated as nodal metastasis is rare[28]. LWR has the advantage of early resumption of diet, early return of bowel function, shorter hospital stay and decreased duration of parenteral or epidural analgesia[58]. Lee *et al*[59] study concluded that LWR can be safely performed and have better outcome in terms of recovery after surgery regardless of tumor size and location. Kim *et al*[60] study concluded that LWR is safe and feasible for small to medium sized gastroduodenal tumors irrespective of location in cardia or pylorus. However, they recommended careful consideration of direction of stapling for exogastric resection of submucosal tumors located in antrum, lesser curvature and pylorus to prevent gastric outlet obstruction.

Endoscopic enucleation and other related procedures are more feasible for GISTs less than 5 cm[61]. Complete resection of GIST is indicated with endoscopic enucleation in the presence of a pseudo capsule. According to location in the gastric wall, GISTs are classified in to several types such as type 1 [very narrow connection with muscularis propria (MP) layer which protrudes in to the lumen], type 2 (wide based connection with MP layer and protrudes in the luminal side at obtuse angle), type 3 (located in the middle of gastric wall) and type 4 (protrudes into the serosal surface of gastric wall)[61]. This classification is very important when considering endoscopic enucleation. Endoscopic enucleation is best suitable for type 1 because of narrow connection to the MP layer and can be attempted for type 2. Type 3 and type 4 cannot be completely resected by endoscopic enucleation and hence endoscopic full-thickness resection (EFTR), laparoscopic and endoscopic cooperative surgery (LECS), laparoscopic-assisted endoscopic full-thickness resection (LAEFR) and non-exposed wall-inversion surgery (NEWS) should be considered[61]. Endoscopic enucleation includes various techniques like endoscopic submucosal dissection (ESD)[62], endoscopic muscularis dissection (EMD)[63] and endoscopic submucosal tunnel dissection (ESTD)[64]. Bialek *et al*[62] evaluated the efficacy, safety and outcomes of ESD for gastric sub epithelial tumors. Results showed 47% (17/37) sub epithelial tumors were GISTs, overall rate of R_0 resection was 81.1% (30/37), and perforation rate was 5.4%[62]. Liu *et al*[63] evaluated the feasibility and safety of EMD. Results showed that 51.6% (16/31) were GISTs, 96.8% (30/31) were completely resected, perforation occurred in 12.9% (4/31, all of which were managed by

endoscopic methods)[63]. ESTD procedure involves creation of the submucosal tunnel, dissection of the submucosal tumor (SMT) and closure of mucosal entry with hemostatic clips[64]. Gong *et al*[64] evaluated the feasibility and safety of ESTD in upper gastrointestinal SMTs. Results showed that 58.3% (7/12) were GISTs, complete tumor resection was achieved in all patients, *en bloc* resection in 83.3% (10/12, other 2 lesions were resected in 2 pieces) and 2 patients had both pneumothorax and subcutaneous emphysema which were managed conservatively[64]. Disadvantages of endoscopic techniques include tumor recurrence and peritoneal seeding secondary to perforation. It is unclear whether there is remnant GIST tissue after dissection causing tumor recurrence, although the dissection site is usually ablated with electrical knife or snare. Perforation occurs due to pseudo capsule injury during difficult MP layer dissection which increases the chance of peritoneal seeding. Peritoneal seeding is associated with poor prognosis because of increased tumor recurrence.

EFTR without laparoscopic assistance procedure involves introducing a single-chamber gastroscope into the stomach with a transparent cap attached to its tip. Dots are marked around the lesion and submucosal injection is done using normal saline with 1% indigo carmine and epinephrine (1:100000). Hook knife and IT knife are used to incise superficial layers overlying the SMT and snare is used to remove the mucosal and submucosal layers of gastric wall. Hook knife and IT knife are used to make circumferential dissection around the border of SMT. To visualize the SMT clearly, submucosal injection can be done again in the lower border of the tumor as needed. After the MP layer is reached and root of the tumor is exposed, gastric fluid is extracted as much as possible. Active perforation is made with the help of hook knife. After the tumor is completely exposed, SMT is removed *en bloc* with the snare. Dual channel gastroscope can be used for tumors with a broad basement which has the advantage of passing two snares through the accessory channels in to the gastric cavity. Tumor body is grasped with one snare and the other snare is used to *en bloc* enucleate the tumor along with the attached serosal layer. Titanium clips are used to close the defect in gastric wall. Paracentesis can be performed if there are signs of pneumoperitoneum during the procedure. Feng *et al*[65] evaluated the efficacy and safety of EFTR in 48 patients with gastric SMTs. Results showed that 43/48 had GIST, no post-EFTR complication such as bleeding or peritonitis, 5 had moderate postoperative abdominal distension because of air filtration (3 had abdominal paracentesis and the other 2 were managed conservatively)[65]. Zhou *et al*[66] evaluated the efficacy, feasibility and safety of EFTR for gastric SMTs originating from MP layer. Results showed that 16/26 were GISTs, *en bloc* resection rate was 100% and no major complications[66]. In general, there is a risk of peritoneal seeding with EFTR because it involves creating an active large perforation and hence gentle handling of GIST is necessary to maintain an intact pseudo capsule to prevent peritoneal seeding.

LECS has advantage over LWR especially for gastric SMTs located near esophagogastric junction or pyloric region because SMTs can be located accurately using endoscope and the resection of healthy stomach can be minimized[67]. The best indication for LECS is for gastric GISTs originating from MP layer which are intraluminal[61]. First, Argon plasma coagulation (APC) can be used to mark the periphery of the tumor[67]. A small incision is made on the marked area using standard needle knife after injecting 10% glycerin into submucosal layer. Using the IT knife, three-fourth of the marked area is cut circumferentially. Next, laparoscopic dissection of seromuscular layer is performed by making an artificial perforation and seromuscular dissection is carried out with ultrasonically activated device[67]. The incision is closed with the help of laparoscopic stapling device[67]. Hiki *et al*[67] analyzed seven patients who underwent LECS for gastric GISTs. Results showed that 6/7 were GISTs, no postoperative complications like bleeding, stenosis or anastomotic leakage, and successful tumor resection was done irrespective of tumor location (esophagogastric junction or pyloric ring). Tsujimoto *et al*[68] evaluated the feasibility and surgical outcomes of LECS for gastric SMTs. The authors found 16/20 were GISTs, no postoperative complications like bleeding, stenosis or anastomotic leakage, and there was no recurrence of tumor[68].

NEWS is a new technique developed to prevent peritoneal seeding from large active perforation and minimize resected tissue volume of stomach[69]. Mitsui *et al*[69] evaluated the efficacy and safety of NEWS in 6 patients with suspected gastric GIST. Results showed that 5/6 were GIST, *en bloc* resection was achieved in all GISTs, perforation occurred in 2/6 cases (1 case had muscle injury leading to perforation during mucosal cutting by endoscopic knife and the other case had laparoscopic mucosal injury leading to perforation during seromuscular cutting), and no postoperative complications[69]. Future studies with large cohort are needed to validate the safety of NEWS before it is standardized for GISTs treatment.

IMATINIB AS ADJUVANT THERAPY

Tumor size, location, mitotic index and tumor rupture are the most important independent prognostic indicators to determine RFS[4]. Multiple stratification schema like National Institutes of Health (NIH) consensus criteria, Armed Forces Institute of Pathology (AFIP) criteria and the modified NIH consensus criteria were developed to predict risk of recurrence[4,70-72]. The most commonly used stratification method is AFIP criteria[73]. AFIP groups 3a and above are considered high risk for recurrence. This corresponds to 5-year recurrence rate of 30% based on nomogram evaluation[73]. DeMatteo *et al*[74] evaluated the overall survival (OS) in 106 patients who had undergone complete gross tumor removal but were considered high risk for recurrence. It was a phase II Z9000 trial lead by ACOSOG and all patients were treated with imatinib 400 mg per day for 1 year[74]. Results showed that OS for

1, 3 and 5-year was 99%, 97% and 83% respectively after a mean follow up of 7.7 years[74]. RFS rate for 1, 3 and 5-year was 96%, 60% and 40% respectively[74]. In the subsequent trial, patients were randomly assigned to receive imatinib 400 mg per day or placebo for one year[75]. RFS at the end of 1 year for imatinib *vs* placebo was 98% *vs* 83% respectively and OS for imatinib *vs* placebo was 99.2% *vs* 99.7% respectively[75]. Li *et al*[76] evaluated RFS in Chinese patients after complete tumor resection of GISTs. All patients in treatment group (56/105) were treated with imatinib 400 mg once a day for 3 years and 49/105 were not treated (control group)[76]. RFS for imatinib *vs* control group at the end of 1year, 2 year and 3 years were 100% *vs* 90%, 96% *vs* 57% and 89% *vs* 48% respectively[76]. All GISTs with size ⩾ 3 cm, small bowel site and high mitotic index were shown to benefit from adjuvant imatinib treatment[50,75]. Joensuu *et al*[77] evaluated the RFS and OS in KIT-positive GISTs treated with imatinib for 3 year *vs* 1 year who had undergone complete tumor resection but considered high risk for recurrence. Results showed that RFS for patients treated with imatinib for 3 year *vs* 1 year were 65.6% *vs* 47.9% respectively and OS for 3 year *vs* 1 year were 92% *vs* 81.7% respectively[77]. Kang *et al*[78] evaluated the efficacy of adjuvant imatinib for 2 years in high risk GISTs with KIT exon 11 mutation after complete resection at four South Korean centers. The results showed median RFS was 58.9 mo compared to 22.7 mo in pre-imatinib era[78]. They also concluded that imatinib is effective in GIST recurrence even after completion of adjuvant imatinib therapy[78].

NEOADJUVANT OR PREOPERATIVE IMATINIB THERAPY

National comprehensive cancer network (NCCN) guidelines recommend neoadjuvant imatinib therapy to reduce tumor size before surgery and minimize morbidity in patients with primary GISTs considered unresectable or resectable with high risk morbidity[73]. Eisenberg *et al*[79] evaluated the safety and efficacy of neoadjuvant imatinib (600 mg/d) in patients with KIT positive primary GIST (⩾ 5 cm, 32 patients) or with operable metastatic/recurrent GIST (⩾ 2 cm, 20 patients). It was a prospective nonrandomized trial and imatinib was continued postoperatively for 2 years[79]. In primary GIST group, preoperative response was partial in 2 patients (7%), stable in 25 (83%) and unknown in 3 (10%); in metastatic or recurrent group, partial in 1 (4.5%), stable in 20 (91%), and progression in 1 (4.5%)[79]. Only 7 (13%) patients did not have any surgery (5 inoperable or unresectable, 1 patient refusal and 1 physician refusal)[79]. The estimated 2-year rate of TTP, PFS, OS in primary *vs* metastatic/recurrent GIST was 13.9% *vs* 13.6%, 82.7% *vs* 77.3% and 93.3% *vs* 90.9% respectively[79].

Fiore *et al*[80] prospectively evaluated the PFS in locally advanced or unresectable primary GISTs treated with preoperative imatinib. All patients who were considered high risk or needed extensive surgery (3 considered unresectable underwent complete resection, 7 who were initially considered to undergo extensive surgery were conservatively operated, 4 who were considered high perioperative risk underwent safe surgery) improved after preoperative imatinib therapy. PFS after 3 years was 77% from the time of initial imatinib treatment[80].

IMATINIB IN METASTATIC GIST

The outcome of advanced GISTs treated with imatinib is not clear. Demetri *et al*[81] evaluated the efficacy of imatinib on antitumor response, safety and tolerability in advanced GISTs. Results showed that 79 patients (53.7%) had partial response, 41 patients (27.9%) had stable disease and in 7 patients (4.8%) response could not be evaluated[81]. Adverse effects related to imatinib therapy were diarrhea, edema (periorbital and leg), fatigue and gastrointestinal bleeding[81]. Overall, the therapy was well tolerated. Blanke *et al*[82] conducted a multicenter randomized phase II trial and they evaluated the efficacy and long-term safety of imatinib (group A 400 *vs* group B 600 mg) in advanced GISTs positive for CD117 antigen. In group A (400 mg, 73 patients), the authors observed GISTs with complete response 0 (0%), partial response 50 (68.5%), stable 10 (13.7%), progressive 11 (15.1%) and unknown 2 (2.7%)[82]. In group B (600 mg, 74 patients), the authors reported GISTS with complete response 2 (2.7%), partial 48 (64.9%), stable 13 (17.6%), progressive 6 (8.1%) and unknown 5 (6.8%)[82]. Overall, imatinib was well tolerated[82]. In the subsequent phase Ⅲ trial, Blanke *et al*[83] evaluated PFS or OS with standard imatinib dose (400 mg) *vs* higher dose (400 mg twice daily) in patients with incurable GISTs. After a median follow up of 4.5 years, median PFS for standard *vs* high dose imatinib was 18 mo *vs* 20 mo, median OS for standard *vs* high dose imatinib was 55 mo *vs* 51 mo respectively[83]. Treatment response in standard *vs* high dose imatinib were divided in to complete response (5% *vs* 3%), partial (40% *vs* 42%), stable (25% *vs* 22%), progressive disease (12% *vs* 10%) and inadequate assessment (10% *vs* 15%) respectively[83]. This study concluded that 400 mg twice daily imatinib was more toxic than 400 mg dose in treatment of incurable GISTs[83]. Debiec-Rychter *et al*[84] evaluated the efficacy of standard dose imatinib (400 mg) *vs* higher dose (400 mg two times daily) in advanced GIST based on mutational status (KIT or PDGFRA). There was a 61% relative risk reduction of PFS in GISTs expressing exon 9 mutation treated with high dose imatinib[84]. Overall, this study concluded that tumor genotype determines PFS and OS in advanced GISTs and also GISTs with KIT exon 9 benefited from 400 mg two times daily imatinib[84].

Heinrich *et al*[85] showed that presence of KIT exon-11 mutation (71.7%) had better treatment outcome with imatinib when compared to KIT exon-9 (44.4%) and wild-type mutation (44.6%) in advanced GISTs.

The authors also showed that there was an improved response rate (complete/partial response) in patients with KIT exon-9 mutation treated with imatinib 800 mg *vs* 400 mg (67% *vs* 17%, $P = 0.02$)[85]. GIST meta-analysis group (MetaGIST) evaluated PFS and OS with imatinib (400 mg *vs* 800 mg) in advanced GISTs[86]. The results showed that there was a small but significant PFS ($P = 0.04$) advantage in high dose (400 mg twice daily) group and no difference in OS between both (400 and 800 mg) groups[86].

SUNITINIB AFTER TREATMENT FAILURE WITH IMATINIB IN ADVANCED GIST

Demetri *et al*[87] evaluated patients treated with sunitinib in advanced GISTS who were intolerant or resistant to previous imatinib treatment. They concluded that median TTP with sunitinib *vs* placebo was 27.3 wk *vs* 6.4 wk respectively[87]. Overall, sunitinib was well tolerated and side effects like nausea, fatigue, skin discoloration and diarrhea were common[87].

REGORAFENIB AFTER TREATMENT FAILURE WITH IMATINIB AND SUNITINIB IN ADVANCED GIST

Demetri *et al*[88] evaluated the efficacy and safety of regorafenib after failure of treatment with imatinib and sunitinib. Results showed that the median PFS in regorafenib *vs* placebo group were 4.8 mo *vs* 0.9 mo respectively[88]. There was no statistical significance in terms of OS between regorafenib and placebo group[88]. Drug related adverse events occurred in 130/132 (98.5%) in regorafenib group and 45/66 (68.2%) in placebo group[88]. The most common adverse effects of regorafenib include hypertension (31/132, 23.5%), hand foot skin reaction (26/132, 19.7%) and diarrhea (7/132, 5.3%)[88]. Overall, this study concluded that regorafenib significantly improved PFS in patients with advanced GISTs who failed treatment with imatinib and sunitinib[88].

FOLLOW-UP AFTER TREATMENT

The goal of follow-up after surgery is early detection and treatment of relapse. CT abdomen and pelvis is used for follow-up. Metastasis of GISTs outside the abdomen is infrequent. MRI or PET-CT can be used as an alternative for follow-up. Annual CT abdomen and pelvis for 5 years is recommended for low risk GISTs after surgery[89]. During adjuvant treatment with imatinib for high risk GISTs, CT abdomen and pelvis is recommended every 6 mo[89]. After adjuvant therapy is stopped, CT is repeated every 3-4 mo for first 2 years and there after every 6-12 mo for 10 years[89].

CONCLUSION

With increasing availability of EUS and improved knowledge of the pathogenesis of GISTs, accurate identification and differentiation of GISTs from other submucosal tumors are achieved. Although surgery is preferred, newer endoscopic techniques can be attempted by experienced endoscopists with the assistance of surgeons in suitable candidates. Neoadjuvant imatinib therapy is recommended for primary GISTs considered unresectable or resectable with high morbidity to reduce the tumor size before surgery and minimize morbidity. Adjuvant therapy with imatinib in intermediate and high risk GISTs improves OS and RFS. Sunitinib and regorafenib can be used in advanced GISTs after treatment failure with imatinib. Multidisciplinary approach involving endoscopist, pathologist, radiologist, medical oncologist and surgeon is required for optimal management of GIST.

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