

·综述·

 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像在甲状旁腺功能亢进症中的应用及进展

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【摘要】 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 对甲状旁腺功能亢进症的术前诊断有较高的灵敏度,联合超声或CT能提高诊断和定位的准确率,尤其是对异位的甲状旁腺腺瘤。随着微创甲状旁腺切除术的发展, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT在术前准确定位上的价值日益凸显。甲状旁腺病灶的大小、生化指标等因素会影响 $^{99}\text{Tc}^{\text{m}}$ -MIBI显像的灵敏度和定位准确率。对于部分难以准确诊断和定位的甲状旁腺功能亢进症患者, ^{11}C -蛋氨酸PET/CT、四维CT、术中放射导航等是目前的研究热点和发展方向。

【关键词】 甲状旁腺功能亢进症; ^{99}m 锝甲氧基异丁基异腈; 体层摄影术,发射型计算机,单光子; 体层摄影术, X线计算机

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【Abstract】 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT exhibited high sensitivity in hyperparathyroidism. Combination of ultrasound or CT can raise the diagnostic and location accuracy, especially in ectopic parathyroid adenoma. With the development of minimally invasive parathyroidectomy, the value of $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT in preoperative location accuracy stands out. Many factors such as size of the gland lesions and biochemical indexes affect the sensitivity and location accuracy of $^{99}\text{Tc}^{\text{m}}$ -MIBI scintigraphy. For the negative imaging hyperparathyroidism patients, ^{11}C -methionine PET/CT, 4D-CT and intraoperative radiation navigation is current research hot spot and development orientation.

【Key words】 Hyperparathyroidism; Technetium Tc ^{99}m sestamibi; Tomography, emission-computed, single-photon; Tomography, X-ray computed

甲状旁腺功能亢进症(简称甲旁亢)是指甲状旁腺分泌过多的甲状旁腺激素,可分为原发性、继发性和三发性。原发性甲状旁腺功能亢进症(primary hyperparathyroidism, PHPT)是由于甲状旁腺本身病变引起的甲状旁腺激素的合成和分泌过多所引起的,病因为甲状旁腺腺瘤(癌)或增生,其中腺瘤占80%~85%,且绝大多数为单发腺瘤,甲状旁腺增生约占10%~15%,甲状旁腺癌所占比例不到1%。继发性甲状旁腺功能亢进症(secondary hyperparathyroidism, SHPT)是由于各种原因所致的低钙血症,刺激甲状旁腺增生肥大,分泌过多甲状旁

腺素(parathyroid hormone, PTH),多见于肾功能不全和骨软化患者。三发性甲旁亢的甲状旁腺长期受低血钙刺激,部分增生组织转变为腺瘤,具有自主分泌过多PTH的能力,多见于慢性肾病患者。

手术是治疗PHPT的有效办法,术前对病变的准确定位至关重要,不仅可缩短术中寻找病灶的时间,使手术范围达到最小,而且也可避免因术中漏诊而再次进行手术。 $^{99}\text{Tc}^{\text{m}}$ -MIBI显像已成为术前诊断和定位甲状旁腺病灶的重要检查方法。下面就 $^{99}\text{Tc}^{\text{m}}$ -MIBI对甲旁亢的诊断价值作一综述。

1 显像原理

$^{99}\text{Tc}^{\text{m}}$ -MIBI在1989年被提出用于甲状旁腺显像^[1],由于具有较 $^{201}\text{TlCl}$ 更高的甲状旁腺的摄取和较 $^{99}\text{Tc}^{\text{m}}$ 更优的物理特性, $^{99}\text{Tc}^{\text{m}}$ -MIBI显像取代了之前的 $^{201}\text{TlCl}$ 而成为甲状旁腺术前显像的常规检查方法。 $^{99}\text{Tc}^{\text{m}}$ -MIBI甲状旁腺显像的方法包括 $^{99}\text{Tc}^{\text{m}}$ -

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MIBI/ $^{99}\text{Tc}^{\text{m}}\text{O}_4(^{123}\text{I})$ 减影法和单核素双时相法。

$^{99}\text{Tc}^{\text{m}}$ -MIBI 双时相法于 1992 年被报道^[2], 其显像原理是利用功能亢进或增生的甲状旁腺组织与正常甲状腺组织不同的洗脱速率。 $^{99}\text{Tc}^{\text{m}}$ -MIBI 在病变组织中聚集并滞留, 而在正常甲状腺组织中洗脱较快, 从而使功能亢进的异常甲状旁腺病灶显影。 $^{99}\text{Tc}^{\text{m}}$ -MIBI 在功能亢进甲状旁腺组织中的滞留被认为与甲状旁腺病灶大小、嗜酸性细胞线粒体含量、细胞周期以及 P-糖蛋白的表达有关; 也有报道认为还与显像技术、生化指标(血钙、PTH 水平)、病灶血流等^[3]有关。

然而, 并非所有的甲状旁腺病灶都能滞留 $^{99}\text{Tc}^{\text{m}}$ -MIBI, 也并非所有的甲状腺组织都能快速洗脱 $^{99}\text{Tc}^{\text{m}}$ -MIBI, 有报道发现 $^{99}\text{Tc}^{\text{m}}$ -MIBI 对病变的甲状腺组织如甲状腺肿、慢性甲状腺炎、甲状腺肿瘤及转移灶等亦有一定的亲和力, 并且延迟显像时唾液腺、颈部肌肉、下颌骨髓可能显像, 从而导致 $^{99}\text{Tc}^{\text{m}}$ -MIBI 甲状旁腺显像结果出现假阴性和假阳性^[4]。

2 $^{99}\text{Tc}^{\text{m}}$ -MIBI 甲状旁腺显像的策略

尽管一些文献报道 $^{99}\text{Tc}^{\text{m}}$ -MIBI/ ^{123}I 双核素减影法在较大的甲状旁腺病灶定位上要优于 $^{99}\text{Tc}^{\text{m}}$ -MIBI 双时相法^[5], 其原因在于 $^{99}\text{Tc}^{\text{m}}$ -MIBI 的非特异性摄取和病灶洗脱速率的增加, 从而导致显像的假阳性和假阴性, 但是 $^{99}\text{Tc}^{\text{m}}$ -MIBI 双时相法简便的技术操作是其目前能够广泛应用的重要原因。

目前关于 $^{99}\text{Tc}^{\text{m}}$ -MIBI 注射后何时进行延迟显像尚无统一标准。Keane 等^[6]比较了 $^{99}\text{Tc}^{\text{m}}$ -MIBI 双时相法不同的延迟时间对诊断准确率的影响, 发现注射后 1~2 h 延迟相的诊断价值最高, 而 3 h 的延迟相诊断价值有限。

有些研究认为, 关注 $^{99}\text{Tc}^{\text{m}}$ -MIBI 早期相显像能提高甲状旁腺患者定位的准确率, 特别是对于病情轻微而延迟相阴性的患者^[7]。有病例报道发现甲状旁腺患者在延迟相中未见 $^{99}\text{Tc}^{\text{m}}$ -MIBI 的摄取, 而在早期相 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像中发现了异位甲状旁腺病灶^[8]。组织病理发现异位腺瘤主要由主细胞构成, 而嗜酸性细胞的比例很小, 从而解释了 $^{99}\text{Tc}^{\text{m}}$ -MIBI 在病灶中并未滞留, 尽管没有延迟相的 $^{99}\text{Tc}^{\text{m}}$ -MIBI 摄取, 利用早期相能够获得异位甲状旁腺腺瘤的准确定位。

选择早期相还是延迟相行 SPECT/CT 亦未达成

共识。Martínez-Rodríguez 等^[9]认为取消延迟相显像对于甲状旁腺瘤的定位灵敏度并无影响, 早期相的平面显像或 SPECT 已经能够准确定位甲状旁腺腺瘤。而 Yang 等^[10]发现 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 早期相与延迟相相对于术前定位的准确率相似, 早期相和延迟相结合 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 的特异度是 100%。

另外, 针孔准直器的应用能很大程度地提高甲状旁腺病灶的检出率。Fuster 等^[11]研究表明, 针孔准直器及平行孔准直器 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像的病灶检出率分别为 74% 和 48%。

3 术前 $^{99}\text{Tc}^{\text{m}}$ -MIBI 不同显像策略及其他影像学方法的比较与联合应用

在没有任何术前显像的情况下, 传统的颈部探查手术对于 PHPT 患者的成功率为 92%~96%, 一直以来都有学者更推荐生化指标检测而非显像来作为甲状旁腺患者的术前常规检查。Wachtel 等^[12]认为, 相比于能够准确定位的甲状旁腺腺瘤, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 显像难以定位体积较小、质量较轻的甲状旁腺病灶以及多发腺体增生, PHPT 患者的术前评估更重要的是生化诊断而非术前显像。

更多的观点认为, 甲状旁腺患者的术前显像能够给手术定位提供帮助, 特别是异位的甲状旁腺腺瘤或者解剖变异的甲状旁腺。微创甲状旁腺切除术将传统的甲状旁腺切除术治愈率从 97.1% 提高到了 99.4%, 术后的并发症发生率从 3.10% 降低到了 1.45%。在许多国家, 微创甲状旁腺切除术已经代替了传统的颈部探查甲状旁腺切除术, 术前准确定位不仅对于微创手术的成功至关重要, 其定位准确率也能影响到手术时间、术中出血以及手术并发症。于是, 许多学者将 SPECT/CT 在微创甲状旁腺切除术前的显像提升到更高的地位。

本文对 PHPT 术前各种影像学检查的诊断价值广为探究, 列举了 2010 年至 2014 年关于甲状旁腺术前不同影像学方法的比较研究(表 1)。

由表 1 可看出, 相比于 $^{99}\text{Tc}^{\text{m}}$ -MIBI 平面显像, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 断层显像提供了三维功能图像, 提高了 PHPT 患者术前定位的准确率。尽管有研究表明, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 与 SPECT 对甲状旁腺病灶的诊断灵敏度相当^[24], 但更多的研究认为 SPECT/CT 比单独 SPECT 及平面显像提供了更可靠的三维解剖结构信息, 其最大的优势在于更准确的

表 1 2010-2014 年关于甲状腺功能亢进症术前不同影像学方法的比较研究
Table 1 Comparative studies of different imaging methods of preoperative hyperparathyroidism from 2010 to 2014

第一作者	发表年份	研究对象	例数	研究内容	影像学方法				
					超声	平面显像	SPECT	SPECT/CT	MRI
Hassler ^[13]	2014	PHPT	51	灵敏度、特异度	-	75%、90%	-	86%、100%	-
		合并甲状腺疾病	24	灵敏度、特异度	-	62%、95%	-	88%、100%	-
		未合并甲状腺疾病	27	灵敏度	-	85%	-	85%	-
Vitetta ^[14]	2014	PHPT	108	灵敏度、特异度	-	78%、94%	-	72%、90%	-
		单一的异位甲状腺腺瘤	18	灵敏度	55.0%	77.7%	-	-	-
Noda ^[15]	2014	PHPT	61	定位准确率	77.0%	75.4%	-	88.5%	-
Zhen ^[16]	2013	SHPT	90	灵敏度、特异度	-	55.6%、100%	-	78.9%、100%	-
Smith ^[17]	2013	PHPT	220	定位准确率	82.0%	85.0%	-	-	-
Michel ^[18]	2013	PHPT	58	灵敏度、阳性预测值	-	88%、93.6%	-	-	94.3%、96.2%
Kwon ^[19]	2013	甲状腺腺瘤	112	灵敏度、阳性预测值	93.1%、96.9%	92.2%、96.9%	-	-	-
Kim ^[20]	2012	PHPT	24	灵敏度	70.8%	75.0%	-	100%	-
Akbaba ^[21]	2012	PHPT	98	定位成功率、灵敏度、特异度、诊断准确率	83.7%、87.2%、25.0%、83.0%	67.3%、70.2%、50.0%、69.4%	72.4%、75.5%、50.0%、74.5%	-	61.2%、63.8%、50.0%、63.3%
Cheung ^[22]	2012	PHPT	meta 分析	灵敏度、阳性预测值	76.1%、93.2%	-	78.9%、90.7%	-	-
Untch ^[23]	2011	PHPT	516	定位准确率	87.0% (有经验的外科医师)	-	76.0%	-	-
Oksüz ^[24]	2011	PHPT、SHPT	60	真阳性率	-	76.0%	97.0%	97.0%	-
Leupe ^[25]	2011	PHPT	368	阳性预测值(左右叶定位/象限定位)	84%、40%	93%、61%	-	-	-
Winmer ^[26]	2010	多发性腺病	30	定位准确率	-	-	13.3%	46.7%	-
Vulpio ^[27]	2010	尿毒症性 SHPT	21	灵敏度、特异度	55%、95%	62%、95%	-	-	-
Pata ^[28]	2010	异位甲状腺	9	检出率	0.0%	78.0%	-	-	-
		PHPT	33	灵敏度、特异度、阳性预测值(左右叶定位)	-	-	80.0%、87.5%、88.9%	93.7%、93.7%、92.9%	-
Patel ^[29]	2010	甲旁腺瘤	59	灵敏度、特异度、阳性预测值(象限定位)	-	-	55.6%、88.5%、62.5%	87.5%、95.5%、87.5%	-
		甲旁腺瘤	59	检出率	64.0%	-	-	90.0%	-

注：表中，PHPT：原发性甲状腺功能亢进症；SHPT：继发性甲状腺功能亢进症；“-”表示未作研究分析。

解剖定位^[30], 尤其是对于异位的体积较小的甲状旁腺腺瘤。Serra 等^[31]发现 SPECT/CT 比单独的 SPECT 能多提供 39% 的 PHPT 或 SHPT 病灶信息。Taieb 等^[32]在系统性研究中发现, 对于异位甲状旁腺腺瘤的精确定位、有过颈部手术史、PHPT 术后复发、甲状旁腺癌远处转移^[33]、PHPT 合并结节性甲状腺肿或多发性内分泌腺病患者中, SPECT/CT 比 SPECT 及平面显像能给甲状旁腺微创手术的术前计划提供更多的帮助。Bural 等^[34]在对 32 例甲旁亢患者 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像中发现, SPECT 发现了 22 例阳性病灶, 而 SPECT/CT 发现了 31 例阳性病灶, 并且小于 10 mm 的甲状旁腺功能亢进病灶并不能靠单独 SPECT 检出。有学者认为, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 应作为 PHPT 微创术前的常规显像, 然而如果考虑到显像的时间以及增加的辐射剂量等因素, 是否应该在 PHPT 微创术前常规使用 SPECT/CT 仍然存在争议^[35]。

超声是最简便的筛查手段。由富有经验的超声医师操作, 合并有甲状腺疾病的甲旁亢患者超声检查的灵敏度和准确率高于 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT。 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 显像优于超声的主要优势在于发现异位甲状旁腺病灶的高灵敏度。目前较为一致的观点是, 在超声阴性或定位不准确的甲旁亢患者中进一步应用 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 显像能提高诊断和定位的准确率; 另一方面, 联合超声或 CT 图像对于 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 的准确定位能提供更多的信息, 尤其是在 PTH 水平低、年龄大以及多发甲状腺结节的患者中^[36]。Cheung 等^[22]通过 Meta 分析得出结论, 超声和 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 在异常甲状旁腺的术前定位中价值相当。

大多数研究认为 MRI 与 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像具有相似的灵敏度和阳性预测值^[37]。MRI 探测甲旁亢病灶的缺点在于其对于小病灶的灵敏度低、误将增生的淋巴结或甲状腺疾病认为是甲状旁腺腺瘤, 而其优点在于没有电离辐射损伤, 以及对术后持续或复发的甲旁亢患者的诊断价值较高。Michel 等^[18]通过比较发现, MRI 相比于 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像对于甲旁亢病灶的探测有更高的灵敏度和阳性预测值, 两者的联合能提高探测异常甲状旁腺的灵敏度和阳性预测值, 减少手术切除范围和手术时间。

CT 在甲旁亢中的应用主要集中在融合图像上, 单独使用 CT 对于甲旁亢病灶的探测准确率较低,

然而 Ernst^[38]发现三期增强 CT 对于甲旁亢病灶的定位有很高的准确率。较新的研究认为, 四维 CT 有更高的灵敏度和定位准确率, 将在后文中详述。

4 $^{99}\text{Tc}^{\text{m}}$ -MIBI 甲旁亢显像的临床影响因素

除了上述的技术因素外, 一些临床因素也影响到 $^{99}\text{Tc}^{\text{m}}$ -MIBI 甲旁亢显像的灵敏度和特异度, 如甲状旁腺病灶的部位、大小、增生的类型、多发腺体疾病、合并有多发甲状腺结节、既往有过颈部手术史而复发的甲旁亢以及病情严重程度的生化指标等。

4.1 病灶的大小

病灶的大小是影响 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像的一个重要因素。Wachtel 等^[12]研究了 2002–2014 年共 2185 例甲旁亢患者的 MIBI 显像, 其中 38.3% 未能准确定位, 这些未定位的患者中, 甲状旁腺的体积更小(平均 1.2 cm)、质量更轻(平均 250 mg)、增生发生率更高(12.8%)、单发腺瘤的发生率更低(73.6%)。Vulpio 等^[27]研究认为, 甲状旁腺病灶的最大长径小于 8 mm、弥漫性甲状旁腺增生、不典型的位置以及合并甲状腺疾病会降低 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像的灵敏度和特异度。Saengsuda^[39]研究发现, $^{99}\text{Tc}^{\text{m}}$ -MIBI 甲状旁腺显像阳性的病灶[(2.28±1.05) cm]显著大于显像阴性的病灶[(1.56±0.58) cm]。尽管目前尚没有研究提出甲状旁腺显像所能探测出的最小病灶大小, 但病灶的大小无疑是影响 $^{99}\text{Tc}^{\text{m}}$ -MIBI 甲状旁腺显像最重要的因素之一。

4.2 病灶的病理

在甲状旁腺病灶中, $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像灵敏度和特异度最高的是单发腺瘤, 而对于甲状旁腺增生和多发腺体疾病, $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像的灵敏度和特异度并不高, 经 Meta 分析其灵敏度和特异度分别为 58% 和 93%^[40]。尽管如此, 有文献报道认为术前 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像或联合超声检查对外科医师是有帮助的^[40]。经内科治疗无效的严重 SHPT 患者需要手术治疗, 其手术失败(持续或复发)的主要原因不能发现异位或额外的甲状旁腺腺瘤, 而对于术后持续或复发的 SHPT 患者, 再次手术前的 MIBI 显像至关重要^[41]。利用双核素减影法、使用针孔准直器、联合 CT 提供三维断层信息等方法可以提高检测 SHPT 的灵敏度。Yang 等^[10]建议对 SHPT 患者应该采用早期和延迟相结合的 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT,

Chroustova 等^[42]建议采用 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/低剂量 CT 联合三维双核素减影来检测病灶。一旦发现异位甲状旁腺病灶,联合 CT(SPECT/CT)或 MRI 对于确定解剖位置和决定最适合的手术方法是非常必要的^[43]。

值得一提的是异位甲状旁腺腺瘤,其异位的位置包括前纵隔、咽后部、甲状腺内部以及颈动脉鞘^[44],其中最常见的是前纵隔。超声和 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 对其灵敏度和特异度都很低,而 SPECT/CT 能显著提高异位甲状旁腺腺瘤的诊断灵敏度和定位的准确率^[45]。Kaushal 等^[46]报道了一例甲状腺内异位甲状腺瘤伴多结节甲状腺肿患者,超声及 CT 均无阳性发现,而 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 则准确地检出并定位异位甲状旁腺腺瘤。Shafiei 等^[47]建议将 SPECT/CT 作为所有可疑异位甲状旁腺腺瘤微创术前的常规显像方法。

4.3 生化指标与甲状旁腺显像的定量相关性

研究证实,甲状旁腺腺瘤的 $^{99}\text{Tc}^{\text{m}}$ -MIBI 最大摄取值,无论在 SPECT/CT 还是平面显像中都与血清 PTH 水平显著相关,并且在年轻患者以及血钙水平较高的患者中更高。这一定量研究表明甲状旁腺 SPECT/CT 与实验室指标、病情严重程度紧密相关,可以用来评估甲状旁腺腺瘤的功能状态、病情严重程度,从而影响外科手术的决策^[48]。

相比于良性甲状旁腺病灶,甲状旁腺癌患者的 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 延迟相有更强的显像剂摄取,甚至高于颌下腺的摄取^[49]。 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 阳性率受血清 Ca^{2+} 和 PTH 浓度影响。Mshelia 等^[50]发现,当 PTH 浓度超过 200 ng/L 时,67% 的甲旁亢患者 MIBI 显像阳性,仅有 9% 的患者显像阴性;而当血清 Ca^{2+} 浓度超过 2.7 mmol/L 时,82% 的甲旁亢患者 MIBI 显像阳性,仅有 14% 的患者显像阴性。当甲旁亢患者的血清 Ca^{2+} 浓度低于 2.51 mmol/L 时, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 显像罕见有阳性发现。甲旁亢患者的 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 和 $^{99}\text{Tc}^{\text{m}}$ -MIBI MDP 骨显像的阳性率都与甲状旁腺腺瘤的大小和 PTH 水平相关^[51]。Hughes 等^[52]发现,随着血清 Ca^{2+} 和 PTH 水平的升高,超声和 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 的定位灵敏度和阳性预测值均显著提高;而在血清 Ca^{2+} 和 PTH 水平较低的情况下,超声比 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 显像有更高的定位灵敏度, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 显像则有较高的阳性预测值。

5 进展与展望

目前,术前利用 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 联合其他影像学检查对甲旁亢患者的诊断和定位有很高的准确率,但是仍然有一小部分患者会出现假阴性或定位不准确。对于术前显像定位失败的患者,Hoda 等^[53]推荐采用双侧颈部探查术及术中 PTH 评估,而非更多的术前显像。如何提高这部分患者的诊断及定位准确率是目前甲状旁腺显像的研究方向。

^{18}F -FDG PET/CT 对 PHPT 的定位诊断仍有争议,其诊断价值并不一定优于 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT^[54]。文献研究证实, ^{11}C -蛋氨酸 PET/CT 对于常规影像如 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像定位失败的甲状旁腺腺瘤患者,能更快、更简便地提供更清晰的图像,且准确率更高^[55]。Caldarella 等^[56]通过 Meta 分析得出结论, ^{11}C -蛋氨酸 PET/CT 对于可疑的甲状旁腺腺瘤是灵敏且可靠的诊断方法,且能够为常规显像技术阴性或定位不明确的腺瘤术前定位提供帮助。对于首诊的 PHPT 患者, ^{11}C -MET PET/CT 并非常规检查,其检查适应证是常规术前 $^{99}\text{Tc}^{\text{m}}$ -MIBI 显像诊断不明确或难以准确定位及手术复发的 PHPT 患者^[57]。此外, ^{18}F -Fluorocholine 经过初步的研究也被认为是异常甲状旁腺患者较为理想的分子探针^[58]。

四维 CT 是一种利用高分辨率图像、多维重建以及灌注特性的新兴技术,把时间因素纳入 CT 扫描图像的三维重建中,较好地消除了呼吸运动伪影。对于甲旁亢患者,四维 CT 提供了平扫、动脉期、早期、延迟静脉相图像,低剂量四维 CT 以及容积重建比 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 具有更高的阳性率、准确率、更清晰的图像以及更低的辐射剂量^[59],甚至对一些隐秘的甲状旁腺病灶和多发腺病也有很好的诊断价值。有学者认为应该考虑用四维 CT 替代常规的 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 作为术前的首选检查^[60]。

合并有甲状腺异常(多结节性甲状腺肿、慢性甲状腺炎、既往有甲状腺切除术史)的甲旁亢患者 $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT/CT 的灵敏度和定位准确率不高。对于合并甲状腺异常的典型位置甲状旁腺病灶,研究发现细针穿刺活检组织的 PTH 浓度检测比常规的活检和 SPECT/CT 有更高的灵敏度^[61]。

Van Hoorn 等^[62]研究发现, $^{99}\text{Tc}^{\text{m}}$ -MIBI SPECT 不同的断层图像重建算法(ReSPECT 和 HOSEM)对甲旁亢显像图像质量和临床诊断准确率有显著的影

响。由此作者认为,应该系统性地比较不同的 SPECT 重建算法来提高临床 SPECT 图像的质量。

微创手术相比传统的甲状旁腺切除术有减少手术时间和手术并发症等优点,微创甲状旁腺切除术前的定位及术中的诊断技术(放射导航手术、术中 PTH 检测)对于手术的成功至关重要。放射导航甲状旁腺切除术的手术成功率能达到 98.7%^[63]。Onoda 等^[64]认为对于纵隔异位甲状旁腺的切除术,术中放射导航能够帮助外科医师精确定位和直接反馈。另有学者认为^[65],术中使用超声或放射性核素导航能缩短手术时间,而两者对手术时间的偏差很低,可以在手术中使用超声取代放射性核素显像,并且能发现核素显像阴性的异常甲状旁腺腺体,而在这一过程中外科医生的经验仍然是无可替代的。此外, van der Vorst 等^[66]首次报道了利用亚甲基蓝和近红外荧光成像技术在术中定位甲状旁腺腺瘤,并且与术前的 ^{99m}Tc -MIBI SPECT 有较好的相关性。

6 结语

目前, ^{99m}Tc -MIBI SPECT/CT 对于甲旁亢的诊断和定位已经取得了较高的准确率。对于某些诊断不明确或难以准确定位的甲旁亢患者,综合利用 PET/CT、四维 CT、术中放射导航等方法能进一步提高诊断的灵敏度和准确率,可以制定更优化的诊疗决策,为外科手术特别是微创术提供重要帮助。

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