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影响软镜钬激光碎石术的清石率的因素

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摘要 肾结石是泌尿外科常见病、多发病。输尿管软镜钬激光碎石作为治疗肾结石最常用的微创技术，近年来发展应用越发广泛。为了更加有效地完成结石治疗，必须了解影响软镜钬激光碎石的相关影响因素。本文结合软镜碎石技术最新研究，着眼清石率这一重要指标，对肾脏解剖结构、结石特征、手术及手术器材以及术后的辅助治疗等影响因素进行总结。

关键词 肾结石；输尿管软镜；钬激光；清石率
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Factors affecting stone-free rate of flexible ureteroscopy with holmium laser lithotripsy

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Abstract

Kidney stones are a common and frequently occurring disease in urology. Flexible ureteroscopy with holmium laser lithotripsy is a widely used minimally invasive technique for treating kidney stones. To effectively complete stone treatment, it is necessary to understand the influencing factors related to flexible ureteroscopy with holmium laser lithotripsy. This article summarizes the latest research on flexible ureteroscopy with holmium laser lithotripsy and focuses on the important indicator of stone-free rate. In addition, the influencing factors including renal anatomy, characteristics of kidney stones, surgical techniques and equipment, and postoperative adjunctive therapy are reviewed.

Key Words Kidney Stones; Flexible Ureteroscopy; Holmium Laser; Stone-Free Rate

肾结石是泌尿外科最常见的疾病，占泌尿外科住院病例的39.33%[1-2]。软镜钬激光碎石术发展至今，手术技术及辅助工具都在不断改进，其适用范围逐渐扩大。清石率是衡量软镜钬激光碎石术手术效果的最重要指标，有哪些因素影响软镜钬激光碎石术的清石率呢？现就影响软镜钬激光碎术的清石率的因素总结如下。

1 肾脏解剖与结石特征

肾脏的解剖与结石的特征共同影响着软镜钬激光碎石术中的手术操作及术后结石粉末及碎片的排出，大部分影响因素已经得到了比较充分的研究，但是随着软镜技术的发展，部分因素已被证实不再是影响术后清石率的影响因素。另外在软镜适用范围不断扩大的同时，不同类型的肾集合系统

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等解剖特征对术后无石率的影响也越来越得到进一步研究。

1.1　肾盂漏斗部夹角(infundibulopelvic angle, IPA)　IPA需要通过静脉尿路造影或者CT尿路造影来进行测量[3]。目前应用最多的测量方法是ELBAHNASY[4-5]的方法：连接上下肾窦边缘的中点作为肾盂中心点，平肾下极的水平线与输尿管两侧交点的中心点，连接两点形成的直线与肾盂肾下盏中轴线相交形成的内角，ELBAHNASY的方法应用广泛，用到的特征点及特征线标记明确，所得的角度能比较好地反映输尿管软镜进入肾下盏以及肾下盏结石排出的实际情况。许多研究表明，过于陡峭的IPA不利于肾下盏结石的治疗。DANILOVIC等[6]的研究表明当IPA＜41 °时，输尿管镜术后残留肾结石碎片的可能性更高。RESORLU等[7]的研究表明，在IPA＞45 °的患者中，输尿管软镜无石率高达91.3%，而在IPA＜45 °的患者中输尿管软镜无石率只有65%，两者的差异显著；TASTEMUR等[8]发现IPA＜42.65 °是增加下极肾结石成功率的独立危险因素。另有学者[9-10]认为IPA＜30 °是结石残留的风险因素。IPA过陡，软镜就需要更大的弯曲角度，这会导致碎石及取石操作的难度增加，还会增加输尿管软镜以及光纤的损伤风险[11-12]，IPA同样影响碎石后的排石过程，较陡的IPA不利于结石粉末随着尿液排出体外。尽管IPA是影响输尿管软镜碎石术的不利因素，但是通过术前对结石的影像学分析以及提高手术医生的操作技巧与熟练度仍然可以有效治疗IPA偏小的结石患者[10]。

1.2　肾下盏漏斗部长度(infundibular length, IL)　IL为肾盂到肾下盏最低点漏斗部的长度，表示的是输尿管软镜从肾盂到达结石部位需要经过的距离，也是结石碎片排入肾盂的位移。RESORLU等[13]研究发现结石清除组平均IL小于结石残留组，但是没有统计学意义。ÜRGE等[14]报告IL影响手术成功率与无石率，IL越大，成功率与无石率越低，截断值为22 mm。TASTEMUR等[8]发现IL＞27.5 mm是增加下极肾结石成功率的独立危险因素。IL越长，肾下盏结石到肾盂的距离越远，下盏结构也更加复杂，尿流更易形成紊流，因此增加了软镜碎石的难度以及结石碎片排出的阻力。

1.3　肾下盏漏斗颈宽度(infundibular width, IW)　IW为肾下盏漏斗部最窄处的直径。在以往评估体外冲击波碎石(extracorporeal shock wave lithotripsy, ESWL)术后无石率时，IW过窄是术后残石的危险因素，因为ESWL多将石头碎块化，过于狭窄的漏斗颈妨碍了结石碎片的排出。但是最近的研究发现IW与软镜钬激光术后无石率的关系并没有那么显著，RESORLU等[13]、KARIM等[9]以及SARI等[15]均认为IW对的肾下盏输尿管软镜的无石率没有影响，这跟输尿管软镜可以到达结石所在部位并将其粉末化有关，结石粉末的直径远小于IW，在输尿管软镜碎石后可以顺利排出体外。

1.4　肾盂肾下盏高度(caliceal pelvic height, CPH)　CPH为肾盂到肾下盏最低点的垂直高度。CPH最早用于ESWL后排石的研究[16]，用于输尿管软镜后排石研究不多，RESORLU等[13]对67例因肾下盏结石行输尿管软镜的患者进行了回顾性分析，结石清除组平均CPH为(20.74±6.67) mm，结石残留组平均CPH为(23.23±4.97) mm，P=0.07。考虑到样本量较小，后续有学者进一步对其进行了研究并加大了样本量。朱学华等[17]对201例行输尿管软镜的肾结石患者进行回顾性分析，结石清除组平均CPH为(17.0±4.3) mm，结石残留组平均CPH为(21.8±5.3) mm，两者的差异显著，P＜0.001。从物理的角度来说，CPH反映了结石从肾下盏排入肾盂过程中克服重力做功的大小，若CPH较大，则结石更难排出。

1.5　肾积水程度　肾积水会导致肾脏集合系统结构发生改变。肾积水的程度越严重，则尿液在肾脏集合系统各部位的流速就越低，进而尿液对结石粉末的剪切力就越小，导致无石率下降[18]。刘佳等[19]报告轻度及中度肾积水的患者输尿管软镜的残石率为8.00%；重度肾积水组患者输尿管软镜残石率为30.23%，在ERGANI等[20]的研究中，轻度肾积水患者输尿管软镜的无石率为28%，中度肾积水无石率为16%，重度肾积水无石率为12%，极重度肾积水无石率为2%，无石率大致随着肾积水的加重而降低。据此，对于中重度积水的结石患者，预期输尿管软镜术后清石率低的患者可行经皮肾镜等其他治疗方式。

1.6　结石的负荷　结石的负荷也叫结石的大小。结石负荷通过结石直径(累积直径)、结石面积、结石体积等来描述。结石直径较大，软镜钬激光碎石术后无石率明显较低已经得到了充分的研究[21-22]。考虑到结石的宽度和厚度，许多研究开选择结石体积来描述结石负荷。结石体积的计算方式有球体公式、椭球体公式以及阿克曼公式[23]，其中椭球公

式对结石体积的估算较为准确,以上公式适用于形状较规则的结石,对于复杂形状的结石,可以通过CT扫描软件或深度学习系统得到[24-25],除此之外还有用于输尿管软镜术中准确测量结石体积的工具[26]。根据MERIGOT DE TREIGNY等[27]和VURUSKAN等[28]的研究,对于累计结石直径大于1 cm或结石数量大于4时,用结石体积来预测输尿管软镜无石率相比于累计结石直径更加有效。ITO等[29]与MERIGOT DE TREIGNY等[27]认为结石体积大于1 120～1 131 mm^3是影响钬激光碎石术后清石率的不利因素。

1.7 结石的密度 结石密度在研究中通常使用结石的CT值来表示。更大的结石CT值意味着钙、磷等成分含量越高,结石的实际密度以及硬度也会随之而增大,在术中更难将结石粉末化[30],也更难随尿液排出体外,相关研究[31]也证实了这一点。ÖZTEKIN等[32]得出了结石密度>1 100 Hu是影响输尿管软镜无石率的因素这一结论。结石的密度又可用CT平均值及CT最大值来表示。朱学华等[17]对201例行输尿管软镜患者的结石CT平均值及CT最大值进行回顾性分析,结石清除组结石CT平均值为(548.7±273.7)Hu,结石CT最大值为1 049.0(240.0～2 134.0)Hu;结石残留组结石CT平均值为(734.2±299.1)Hu,结石CT最大值为1 266.0(304.0～1 819.0)Hu,两组的差异显著(P<0.001)。这说明结石的CT最大值及平均值皆与软镜钬激光术后清石率相关。

1.8 肾盂肾盏分枝状结构 SAMPAIO等[33]根据肾盏的上下组及中部肾盏的引流情况对肾集合系统做了最经典的分类。但是,该分类源于70例尸体140个肾脏标本,由于数量和技术的局限性,对临床治疗指导意义不足[34],但仍为最早最经典的肾集合系统的分类。2018年TAKAZAWA等[35]在研究了492个肾脏的CT三维重建后,提出将肾盏由上至下分为5组,分别是顶组、上组、中组、下组、底组,在上中下组又将肾盏分为前后肾盏,这样每个肾盏都可以被准确描述到;根据肾盂的分支情况将肾集合系统分为四型从而可以更好地指导肾结石软镜钬激光碎石的治疗。2021年ZHU等[36]在TAKAZAWA等的研究基础上综合考虑肾下盏肾盂夹角等解剖因素,重点关注狭而陡的肾下盏,用以更好地指导软镜钬激光碎石治疗肾下盏结石。李文成等[37]根据术中所见中组肾盏分布及上下盏位置关系,将肾集合系统分为水平分布型、居上型、居下型和垂直分布型,分类的视角从影像学转为输尿管软镜术者,在临床应用中取得了很好的效果,手术医生经过腔内肾盏解剖分类系统的学习后,相较同等输尿管软镜经验的医生,手术时间得到了极大的缩短,且术后3个月的清石率显著提高。

1.9 特殊类型的肾集合系统 马蹄肾(horseshoe kidney,HK)、双肾盂肾盏畸形、盆腔异位肾(pelvic ectopic kidneys,PEK)以及肾移植后的异位肾等,这些特殊解剖类型的肾脏由于尿流缓慢、反复感染等因素,易发生肾结石。

马蹄肾患者中有16%～60%并发肾结石[38]。异常的解剖结构给结石的治疗也带来挑战[39-40]。尽管体外冲击波碎石、输尿管软镜和经皮肾镜皆可用于治疗马蹄肾结石,但经皮肾镜有着更高的优先级别[41],也可以得到较好的清石率[42]。输尿管软镜往往只用于经皮肾镜或体外冲击波碎石之后的补充。多项研究[43-44]表明输尿管软镜比体外冲击波碎石具有更高的清石率。随着新型输尿管软镜的问世,以及输尿管通道鞘和套石篮的应用,输尿管软镜治疗马蹄肾结石的疗效可以等同于经皮肾镜[45-46],可作为一线治疗[47]。SINGH等[48]认为,对于多个小盏结石可首选输尿管软镜,对于结石负荷<1.5 cm且CT值<1 000 Hu的结石也可首选输尿管软镜,对于大于2 cm且低密度的结石,也可行分期输尿管软镜。PALMERO等[49]则将HK结石输尿管软镜治疗的适应证放宽到了结石小于3 cm。

盆腔异位肾发病率低,约为五千分之一[50]。由于输尿管的位置和临近脏器的毗邻以及肾脏血供不同,行腹腔镜手术或者经皮经腹膜肾镜要比解剖结构正常的肾脏复杂的多。盆腔较深的位置和不良的输尿管引流也使得体外冲击波碎石难以发挥良好的治疗效果。BOZKURT等[51]认为,对于盆腔异位肾并发中小结石且无输尿管开口异位及输尿管狭窄的患者,输尿管软镜是一种更安全有效的方式。对于较大的结石,则更推荐腹腔镜、经皮肾镜以获得更好的清石率[52]。

2 手术及手术器材

2.1 手术经验 尽管结石治疗方面有诊疗指南及较多的专家共识,但实施手术的医生的实践经验仍存在很大差异[53]。资料表明,输尿管软镜的术前准备、术中手术要点的掌握、术后的辅助治疗以及手术器械的维护等多个方面都会影响输尿管软镜的

清石率[54]。手术操作技能以往通过手术室带教得到提升[55]，现有的输尿管软镜培训教程以及高度仿真的模拟训练教学有助于更好地提高临床医师的手术技能[56-57]，从而提高手术的清石率。

2.2　手术器材　以往术中对于CT值较大的结石常推荐将其碎块化以便用套石网篮等将碎块取出，对于CT值较小的结石则推荐将结石粉末化自然排出。因此在手术过程中使用不同的器械会有不同的清石效果。

2.2.1　*术前预置输尿管支架(preoperative stenting，POS)的应用*　一方面，POS可以直接提高输尿管软镜的即时清石率[58]，另一方面，POS也增加了插入输尿管通道鞘的成功率，间接起到了提高清石率的效果。值得注意的是儿童患者POS的获益并不明显，甚至还会增加感染风险。因此，不提倡常规行POS，对于儿童患者可先通过硬性输尿管镜来评估是否需行POS[59]。

2.2.2　*输尿管通道鞘(ureteral access sheath，UAS)*　作为输尿管软镜的重要辅助工具，UAS的使用能够提高视野的可见度，且更便于术中取石，因此可以大大提高输尿管软镜的清石率[60]。置入UAS前预置输尿管支架或使用西洛多辛有助于UAS的顺利置入[61]。带有吸引功能的UAS可以有效的提高输尿管软镜的即时清石率[62]；相比传统的UAS位于肾盂输尿管连接部下方，CHEN等[63]研发的新型柔性真空辅助输尿管通路鞘可以穿过UPJ进入肾盂和肾盏，并可以在控制肾内压的同时进行高速灌洗，可以在术中就达到较好的清石效果。

2.2.3　*输尿管软镜新技术*　与传统的F-URS相比，近年来研发的新型F-URS带有负压抽吸装置、集石器、真空抽吸系统、灌注系统等，可以在碎石时一并将结石碎片吸出，进而提高输尿管软镜的清石率。DENG等[64]研发的可以自动监测并控制肾盂内压的F-URS，可以快速恒压吸出粉碎后的结石粉末，极大地提高了清石率。GAN等[65]、LAI等[66]设计的硕通输尿管镜也通过术中冲洗和真空吸引系统及改进的UAS实现了较高的即时清石率。

2.2.4　*生物凝胶*　考虑到将结石粉末化的清石率低于碎石加套石篮取石，HAUSMANN等[67]利用生物凝胶来吸附并除去因体积太小而无法被套石篮取出的结石粉末，得到了较好的清石效果。

2.2.5　*冲洗液*　ULKER等[68]通过体外实验发现，在视野血染的情况下，使用蒸馏水做冲洗液时与使用等渗盐水做冲洗液相比，可以获得更加清晰的视野；PIRANI等[69]进一步研究也证实了蒸馏水冲洗不会增加低钠血症的发生率。

2.2.6　*麻醉类型与术中诱导呼吸暂停*　GADZHIEV等[70]实践中发现，在全身麻醉行输尿管软镜期间使用呼吸暂停可以避免不必要的肾脏运动，有助于术中的精细操作特别是碎石过程。术中诱导呼吸暂停会不会导致呼吸系统并发症呢？HO等[71]不建议术中诱导呼吸暂停，他认为呼吸运动对输尿管软镜的影响可以通过手术方式来避免，比如在结石远离镜头时再开动激光便可以抵消呼吸偏移引起的肾脏相对位移。

3　术后的辅助治疗

在输尿管软镜之后，结石碎片和粉末会在重力作用下沉积在肾下盏。常规促进结石碎片排出的医嘱包括大量饮水、适度增加体育锻炼等，但是这些方法的效果不尽如人意，仍然有部分结石碎片难以顺利排出。术后辅助结石碎片及粉末排出的方法有体外物理振动排石、口服药物等。

3.1　体外物理振动排石　与单纯的输尿管软镜相比，输尿管软镜联合物理振动排石(external physical vibration lithecbole，EPVL)对残石主动施以外来的能量[72]，可以有效提高清石率[73]，并且随着更早期的EPVL介入，可以得到更好的治疗效果，应用EPVL的最佳时机为输尿管软镜术后3 d[74]。

3.2　药物治疗　在碎石后，服用排石药物可以起到利尿、松弛平滑肌等作用，因此服用排石药物也可以得到很好的效果[75]。

4　总结

输尿管软镜的清石率受到多因素的影响。结石的特征、肾脏的解剖结构、不同的肾集合系统类型对于输尿管软镜的治疗有着巨大的影响，术中使用套石网篮、输尿管通道鞘、新型输尿管软镜、生物黏附凝胶等，术后辅助使用体外物理振动排石和排石药物可以有效提高输尿管软镜的清石率。临床医师要通过不断提高自己的手术技能，术前正确评估并选择合适的治疗手段，术中视情况选用高效的手术设备工具，术后联合辅助治疗以达到提高输尿管软镜清石率的目的。

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(下转第553页)