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CONTEMPORARY MANAGEMENT OF WOLFF–PARKINSON–WHITE SYNDROME IN CHILDREN

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Abstract: Wolff-Parkinson-White (WPW) syndrome is a congenital heart disease that involves an accessory electrical pathway between the atria and ventricles, and in children, it may produce episodes of rapid heart rhythm, most commonly atrioventricular reentrant tachycardia and less commonly atrial fibrillation that may conduct very rapidly to the ventricles and very rarely precipitate ventricular fibrillation. WPW syndrome is diagnosed by the WPW pattern on the electrocardiogram in approximately 0.15% to 0.25% of the general population, and a significant proportion of those children will have symptomatic episodes during childhood or adolescence, while sudden cardiac death is rare in WPW syndrome, but children may have a relatively higher risk compared with adults, especially if they have very rapid-conducting or multiple accessory pathways. In the past, pediatric management was generally pharmacologic therapy and a watchful waiting approach in asymptomatic children given the perceived procedural risks, however, the situation has changed with 3D mapping, improved catheters, and safer energy delivery, and invasive therapy is now much safer and more effective. Consequently, in the past 15 years, catheter ablation has emerged as a first-line therapy and often curative procedure in children and has shifted the treatment paradigm toward earlier definitive therapy. Despite this, antiarrhythmic drugs remain important in the acute management of arrhythmias and as a bridge therapy in selected patients, particularly infants and smaller children who may not be suitable candidates for ablation at present, and surgical ablation, once the mainstay of definitive therapy, is now rarely required but still has a place in selected cases. Therefore, ongoing familiarity with the use of these therapeutic modalities and when to select one therapy over another will help to optimize outcomes and reduce long-term arrhythmic risk in children with WPW.
Keywords: Wolff–Parkinson–White syndrome, pediatric arrhythmia, supraventricular tachycardia, catheter ablation.

Introduction. Wolff-Parkinson-White (WPW) syndrome in children is defined by the presence of an accessory pathway between the atria and the ventricles that may contribute to the development of supraventricular tachycardia (SVT) and, very rarely, sudden cardiac death. The WPW electrocardiographic pattern is present in 0.15-0.25% of the general population, and approximately one-third will develop an arrhythmia over the next decade, because sudden death is rare but is more common in younger patients and occurs early in life with serious events estimated at 0.8-1.9/1000 patient-years in children [1]. Children, and in particular those under the age of 10, are responsible for the majority of ventricular fibrillation in WPW, therefore treatment options include medical therapy, catheter ablation, and surgery in selected cases, according to the risk [2]. The management of WPW has changed over the last decade towards earlier and more definitive therapy, since many pediatric cardiologists have shifted towards a lower threshold for catheter ablation, even in asymptomatic children, given the safety and efficacy of modern techniques [1,3]. This review will describe current therapies for WPW in children between 2010 and 2025, compare safety and outcomes, and provide a comprehensive summary of the important trials and guideline recommendations.

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Methodology. A systematic review of the literature published from 2010 to 2025 was performed using PubMed and Google Scholar, searching for articles containing the keywords "pediatric WPW catheter ablation," "Wolff-Parkinson-White surgery children," "antiarrhythmic drugs WPW children," and the like, and studies were preferred if they provided the best evidence available, including large clinical series, randomized trials, meta-analyses, and expert consensus documents. Reference lists of key reviews and major guidelines, such as PACES/HRS and ACC/AHA statements, were also searched because they often contain relevant information. The main treatment options, including pharmacologic therapy, catheter ablation (radiofrequency and cryoablation), surgical ablation, and emerging technologies, were compared in terms of indications, efficacy, and complications, while both acute and long-term outcomes in children were extracted to construct comparative tables and figures.

Results. In pediatric WPW, the goal of medical therapy is primarily symptom control, since no medication reliably eliminates the accessory pathway. Acute SVT is typically managed with initial vagal maneuvers followed by rapid IV adenosine for orthodromic AVRT if the child is stable, while for hemodynamically unstable atrial fibrillation or flutter with pre-excitation, IV procainamide (or ibutilide) is used to slow conduction across the accessory pathway. AV nodal blockers (adenosine, non-dihydropyridine calcium channel blockers, digoxin) are contraindicated in pre-excited AF since they may trigger ventricular fibrillation [2].

Chronic therapy involves beta blockers (e.g. propranolol approximately 2-4 mg/kg/day) as the first line when control of frequent SVT is required, which is more common in infants, and Class IC drugs (flecainide or propafenone) are highly effective for WPW-related SVT, while class III agents (sotalol, amiodarone) are generally reserved for refractory cases [3]. In practice, flecainide or propafenone monotherapy will terminate most episodes, but breakthrough events are common and many children eventually undergo ablation when feasible. For example, multicenter data on infants with WPW receiving propranolol shows that >50% will relapse and many will eventually undergo ablation, consequently, chronic medication most often serves as a bridge to ablation rather than a definitive long-term solution. Moreover, digoxin and nondihydropyridine calcium channel blockers should be avoided in WPW, as they may shorten atrial refractoriness and increase accessory pathway conduction, and in summary, drugs may provide temporary control but do not change the underlying risk, therefore, most children managed medically will be a candidate for ablation at an appropriate time [2].

Catheter ablation is the definitive curative treatment of pediatric WPW, as it eradicates the accessory pathway, prevents recurrences of SVT, and decreases the risk of sudden cardiac death. Results of contemporary pediatric series are excellent, with complication rates very low, and a large prospective registry of >2000 patients showed that prophylactic RF ablation was successful in ~98.5% of cases, and no patient developed malignant arrhythmias or ventricular fibrillation during long-term follow-up, whereas ~1.5% of untreated patients (mostly children) developed VF [2]. Meta-analyses have demonstrated pooled success rates of >94% for RF ablation of WPW, recurrences of ~6% (most treated with a simple touch-up procedure), and major complications in the range of 1-2%, therefore, overall, ablation provides a durable cure with a very strong safety profile when performed in experienced pediatric centers [1].

In current pediatric practice, 3D electroanatomical mapping has been a game-changer, because by allowing for high fidelity localization of the accessory pathway and essentially eliminating the need for fluoroscopy, 3D-guided ablation has become associated with acute success rates >95% (even in infants) with essentially no radiation exposure [1]. For pathways close to the His bundle or mid/septum, cryoablation is usually the preferred method because of the safety

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margin surrounding the AV node, while its acute success is slightly lower than RF for septal pathways (~86-90% with cryo vs ~94-95% with RF). However, cryo's ability to test lesions and reverse conduction injury in the setting of AV block has made permanent AV block an essentially extinct complication in experienced hands. Therefore, when centers use RF for non-septal pathways and cryo for septal pathways, overall outcomes are similar, with acute success typically exceeding 90-95%, and if one includes touch-up procedures, long-term cure approaching 99% in large 3D-mapping cohorts, moreover, major complications such as complete heart block, perforation, or thromboembolism are exceedingly rare (<2% in contemporary series) [1,5].

Consequently, RF ablation will cure most children in a single procedure with ~5-10% requiring a second procedure, and cryoablation cures slightly less, but at a higher safety margin to the AV node, and when judiciously used for septal accessory pathways, cryoablation has similar success rates to RF and reduces serious complications to near zero [1,2,5].

This flowchart is designed to integrate risk stratification, symptom assessment, and the decision to proceed with noninvasive versus invasive testing to determine the appropriate treatment strategy for WPW, and it also differentiates between WPW "pattern" and WPW "syndrome." There is a trend toward younger age at EPS and catheter ablation because early intervention is often necessary. Early EPS is recommended, particularly if high-risk features are identified, such as a very short accessory pathway refractory period, multiple pathways, or a history of arrhythmic symptoms.

AMERICAN ACADEMIC PUBLISHER

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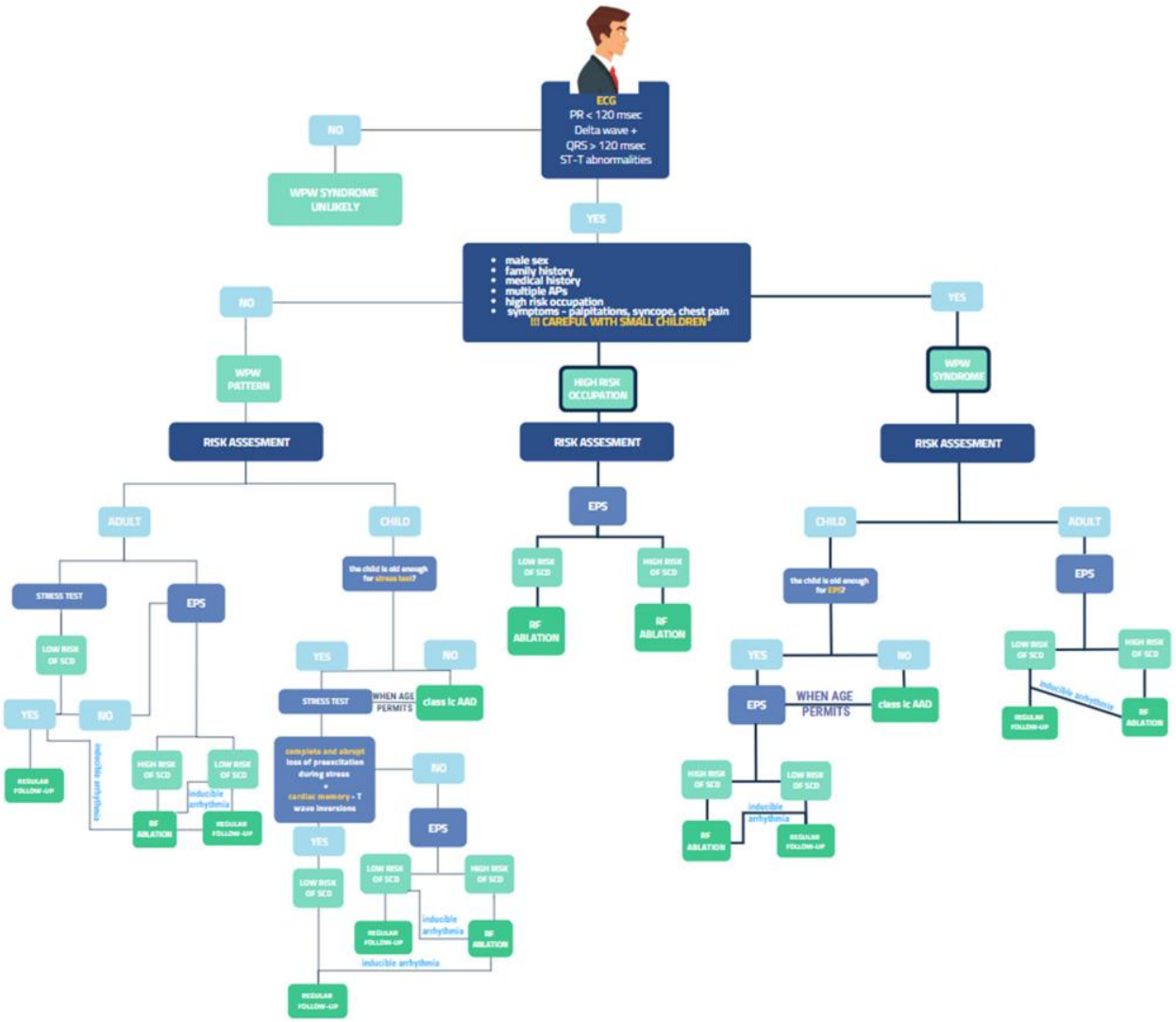

Figure 1. Example treatment algorithm for pediatric WPW (reproduced from Vătășescu et al. 2024).

Children are not simply small adults, and smaller hearts and more difficult vascular access make the procedure more challenging. Ablation below approximately 15-20 kg is without doubt more difficult, but in experienced hands it is certainly possible, and one registry reported an approximately 95% success rate for ablation in children weighing <15 kg, predominantly using non-irrigated and cryo catheters without major complications [5]. The advent of deflectable sheaths, intracardiac echo, and contact-force catheters have also made the procedure safer, and most importantly, successful WPW ablation in infancy or childhood appears to be associated with long-term benefit, as follow-up studies have shown that children treated with catheter ablation have a lower risk of heart failure and sudden cardiac death than those treated medically [1].

Surgical division of the accessory pathway is no longer commonly performed today, but it is an important historical landmark, and surgical ablation of the accessory pathway was performed either during open-heart surgery for WPW or in combination with repair of congenital heart

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disease. In a classic study of 55 children with a mean age of 10 years, mostly endocardial surgical division was associated with a 92% cure rate and no late arrhythmic deaths; however, there were significant trade-offs, including early mortality of 3.6%, and hospitalization and recovery were prolonged. In the era of modern catheter ablation, surgery is now reserved for very select circumstances, usually when multiple attempts at catheter ablation have failed, or when the child is already going to the operating room for another intracardiac repair, because surgical success rates are still high, usually >90%, but surgical ablation carries the risks of cardiopulmonary bypass [6]. In short, surgery works, but it is invasive, and modern management very much favours catheter ablation, with surgery being reserved for a last resort.

Several newer technologies have been developed over the last several years to improve the safety and efficacy of ablation, and pulsed-field ablation (PFA), a nonthermal ablation technology utilizing pulsed electric fields, has gained attention recently for adult AF ablation and is also being studied for WPW. Early adult pilot studies suggest that focal PFA can selectively target and ablate accessory pathway tissue with high efficacy while sparing adjacent tissue, which is promising, but there is no pediatric clinical data yet, and its role in children is still to be determined [1].

In addition to PFA, advanced mapping technologies are helping operators better localize accessory pathways, and high-resolution microelectrode catheters have been used to improve localization during WPW ablation. Robotics and remote magnetic navigation are used in some centers to reduce fluoroscopy exposure and improve catheter stability, but their use in pediatrics is still very limited, and completely noninvasive technologies, including stereotactic radiotherapy for arrhythmias, are still experimental at this time. For now, these emerging technologies are best considered as adjuncts to, rather than alternatives for, radiofrequency or cryoablation, and ongoing studies will help clarify the proper place and role for these technologies in the care of pediatric WPW patients.

Table 1 compares the major therapies for pediatric WPW. Pharmacologic therapy with antiarrhythmics and beta blockers may decrease the frequency of episodes of SVT, but is otherwise palliative, and control is achieved in ~60-80% of cases, although recurrences are common. Catheter ablation, which can be performed using radiofrequency or cryo, is generally curative, with ~95% acute success and ~99% long term cure after repeat procedures, while complications from ablation are rare, occurring in ~1-2% of cases [1,2,5]. Surgical ablation is effective as well, with a ~92% cure rate, but it is associated with a higher perioperative risk, including ~3.6% mortality [6].

Table 1. Comparison of treatment modalities for pediatric WPW syndrome.

Modality	**Indications**	**Acute Success**	**Recurrence / Long-Term Outcome**	**Complications / Notes**
Antiarrhythmic drugs (flecainide, propafenone, etc.)	Symptomatic SVT control; bridge therapy; noninvasive risk reduction	Variable; many SVTs (>50%) can be terminated or suppressed	High recurrence of arrhythmia; *not curative* – most patients eventually require ablation	Proarrhythmic risk, especially in structural heart disease; do NOT use digoxin/CCBs in WPW
β-Blockers (e.g.	First-line for infants/young	Moderate (controls	Often incomplete; often used as	Generally safe; may slow AV

AMERICAN ACADEMIC PUBLISHER
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propranolol)	children with WPW-related SVT	ventricular rate; may abort SVT)	interim therapy pending ablation	conduction; not definitive therapy
Catheter RF Ablation	Definitive therapy for WPW (symptomatic or high-risk asymptomatic)	≈95% acute success	~5–10% require repeat ablation; overall ~99% long-term success	Major complications in <2% (AV block, perforation, etc.); 3D mapping minimizes fluoroscopy
Catheter Cryoablation	Alternative in high-risk septal APs or very small children	≈86–90% acute success	Slightly higher recurrence (~10–15%) than RF	Excellent safety near AV node (virtually no permanent AV block); often used ~10% of ablations
Surgical Ablation	Reserved for failed catheter ablation or concomitant CHD surgery	≈92% cure rate	~8% (cure 92%) (reoperations infrequent)	Early mortality ~3.6%; long recovery; now rarely performed

Discussion. Over the last 15 years, there has been a paradigm shift in the treatment of WPW patients towards curative therapy, because with the development of better mapping tools and more reliable energy delivery systems, catheter ablation has become very safe and highly effective [1,2]. Acute success rates in experienced centers are generally >94-95%, and if SVT recurs, a repeat procedure will almost always be curative; therefore, many programs now favor early referral for ablation in any child with documented WPW tachycardia and even in asymptomatic children in some instances [1,5]. Recent expert recommendations also take a more nuanced approach to simple "watchful waiting" for asymptomatic WPW, since both the 2012 PACES/HRS statement and more recent expert pathways published in 2025 acknowledge that asymptomatic WPW in children is not entirely benign and that traditional risk markers are imperfect, such as loss of pre-excitation with exercise, which does not completely exclude the possibility of a potentially malignant accessory pathway. Given the limitations of risk stratification and the excellent cure rates achievable with contemporary ablation, it is reasonable to offer ablation to many asymptomatic children, particularly if high-risk features are present, as supported by references [1,4].

There is still a role for pharmacologic therapy in the management of infants who are too small for an ablation, and as a bridge to definitive therapy, but long-term drug therapy is inferior to ablation. There have been few recent pediatric drug trials, and clinical experience suggests that class IC agents (flecainide or propafenone) are generally more effective than beta-blockers in maintaining sinus rhythm in WPW, but they do carry some proarrhythmic risk. Any therapy that does not eliminate the accessory pathway leaves residual risk, whereas successful catheter ablation normalizes long-term outcome [2]. There have been no cases of sudden cardiac death after a pathway was successfully ablated in follow-up studies, and ablation appears to reduce the long-term risk of atrial fibrillation and heart failure in WPW [1].

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Safety is the first consideration in pediatrics, and the modern data are extremely reassuring because contemporary pediatric series have demonstrated major complication rates of <2% for catheter ablation, a testament to how far technology and technique have come [1]. The use of 3D electroanatomic mapping has allowed most cases to be performed with minimal to no fluoroscopy, and smaller and more maneuverable catheters have facilitated access and stabilization on target sites, and cryoenergy has provided an additional safety margin in proximity to the AV node to further reduce the risk of AV block [5]. Including repeat procedures, at least one large cohort has reported a 99% overall cure in children with WPW, without a single case of permanent heart block, and therefore, the evidence supports current guidelines to consider strongly catheter ablation at the time of diagnosis in a child with WPW. This is particularly important, even in those who have relatively infrequent symptoms, given the limitations of risk stratification and the long-term benefits of definitive elimination of the accessory pathway [1,4].

Conclusion. In summary, the management of WPW in children is a risk-benefit equation and the pendulum has swung toward curing the problem, rather than just treating it, because for the symptomatic child, catheter ablation is first line and curative in >95% of patients with very low long-term risk. For the asymptomatic child, the more recent literature supports offering ablation when high-risk features are present, as the AP itself carries a small, but real, risk of adverse events. Medical management is still important, particularly as a bridge to ablation or for infants who are too small for ablation, but medical therapy does not eliminate the risk of arrhythmias, and surgical therapy is rarely indicated in the current era as catheter-based techniques have become so effective and safe. Newer techniques and tools, such as mapping systems and possibly pulsed-field ablation, may make the procedure safer and faster, although there remains a need for strong pediatric data, and consequently, ongoing research includes the best way to assess risk, including how much noninvasive testing versus EP study, and how to manage the smallest of infants. Large registries, such as IMPACT, are helping us understand outcomes by patient size and procedural approach, and thus, on a day-to-day basis, the most important thing is to have a shared decision-making process with families, which involves explaining the excellent outcomes and very low complication rate of modern ablation compared with the limitations of lifelong medical therapy, allowing families to make an informed decision for their child.

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