8.01.34	Hematopoietic Cell Transplantation for Solid Tumors of Childhood		
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Policy Statement

I. Autologous hematopoietic cell transplantation may be considered **medically necessary** for **any** of the following:
   A. Initial treatment of high-risk neuroblastoma
   B. Recurrent or refractory neuroblastoma
   C. Initial treatment of high-risk Ewing sarcoma
   D. Recurrent or refractory Ewing sarcoma
   E. Metastatic retinoblastoma

II. Tandem autologous hematopoietic cell transplantation may be considered **medically necessary** for high-risk neuroblastoma.

III. Autologous hematopoietic cell transplantation is considered **investigational** for **any** of the following:
   A. Initial treatment of low- or intermediate-risk neuroblastoma
   B. Initial treatment of low- or intermediate-risk Ewing sarcoma
   C. Other solid tumors of childhood including, but not limited, to the following:
      1. Osteosarcoma
      2. Retinoblastoma without metastasis
      3. Rhabdomyosarcoma
      4. Wilms tumor

IV. Tandem autologous hematopoietic cell transplantation is considered **investigational** for the treatment of all other types of pediatric solid tumors except high-risk neuroblastoma, as noted above.

V. Allogeneic (myeloablative or nonmyeloablative) hematopoietic cell transplantation is considered **investigational** for treatment of pediatric solid tumors.

VI. Salvage allogeneic hematopoietic cell transplantation for pediatric solid tumors that relapse after autologous transplant or fail to respond is considered **investigational**.

NOTE: Refer to Appendix A to see the policy statement changes (if any) from the previous version.

Policy Guidelines

This policy addresses peripheral neuroblastoma arising from the peripheral nervous system (i.e., neuroblastoma, ganglioneuroblastoma, ganglioneuroma).

Hematopoietic cell transplantation refers to any source of stem cells, i.e., autologous, allogeneic, syngeneic, or umbilical cord blood.

Relapse is defined as tumor recurrence after a prior complete response.

Primary refractory disease is defined as a tumor that does not achieve a complete remission after initial standard-dose chemotherapy.

Coding

CPT centralized codes describing allogeneic and autologous hematopoietic stem cell support services to the hematology section (CPT 38204-38242). Not all codes are applicable for each high-dose chemotherapy/stem cell support procedure. The following range of codes describes services associated with cryopreservation, storage, and thawing of cells (38207-38215):

Thawing and washing of cryopreserved cells:

- **38207:** Transplant preparation of hematopoietic progenitor cells; cryopreservation and storage
- **38208**: Transplant preparation of hematopoietic progenitor cells; thawing of previously frozen harvest, without washing, per donor
- **38209**: Transplant preparation of hematopoietic progenitor cells; thawing of previously frozen harvest, with washing, per donor

Types of cells being depleted:

- **38210**: Transplant preparation of hematopoietic progenitor cells; specific cell depletion within harvest, T-cell depletion
- **38211**: Transplant preparation of hematopoietic progenitor cells; tumor cell depletion
- **38212**: Transplant preparation of hematopoietic progenitor cells; red blood cell removal
- **38213**: Transplant preparation of hematopoietic progenitor cells; platelet depletion
- **38214**: Transplant preparation of hematopoietic progenitor cells; plasma (volume) depletion

Plasma cell concentration:

- **38215**: Transplant preparation of hematopoietic progenitor cells; cell concentration in plasma, mononuclear, or buffy coat layer

Description

Hematopoietic cell transplantation (HCT) is a procedure in which hematopoietic stem cells are infused to restore bone marrow function in cancer patients who receive bone-marrow-toxic doses of drugs, with or without whole body radiotherapy. Stem cells may be obtained from the transplant recipient (autologous HCT) or harvested from a donor (allogeneic HCT). Stem cells may be harvested from bone marrow, peripheral blood, or umbilical cord blood shortly after delivery of neonates.

Related Policies

- Hematopoietic Cell Transplantation for Central Nervous System Embryonal Tumors and Ependymoma

Benefit Application

Benefit determinations should be based in all cases on the applicable contract language. To the extent there are any conflicts between these guidelines and the contract language, the contract language will control. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

Some state or federal mandates (e.g., Federal Employee Program [FEP]) prohibits plans from denying Food and Drug Administration (FDA)-approved technologies as investigational. In these instances, plans may have to consider the coverage eligibility of FDA-approved technologies on the basis of medical necessity alone.

Regulatory Status

The U.S. Food and Drug Administration regulates human cells and tissues intended for implantation, transplantation, or infusion through the Center for Biologics Evaluation and Research, under Code of Federal Regulation, title 21, parts 1270 and 1271. Hematopoietic stem cells are included in these regulations.

Rationale

Background

Solid Tumors of Childhood

Solid tumors of childhood arise from mesodermal, ectodermal, and endodermal cells of origin.[1] Some common solid tumors of childhood are neuroblastoma, Ewing sarcoma/Ewing sarcoma family of tumors (ESFT), Wilms tumor, rhabdomyosarcoma, osteosarcoma, and retinoblastoma.

General Treatment

The prognosis for pediatric solid tumors has improved more recently, mostly due to the application of multiagent chemotherapy and improvements in local control therapy (including aggressive surgery and advancements in radiotherapy).[2] However, patients with metastatic, refractory, or recurrent disease continue to have poor prognoses, and these "high-risk" patients are candidates for more aggressive therapy, including autologous hematopoietic cell transplantation (HCT), to improve event-free survival (EFS) and overall survival (OS).

Descriptions of pediatric-onset solid tumors addressed herein are as follows.

Peripheral Neuroblastoma

Neuroblastoma is the most common extracranial solid tumor of childhood,[1] with approximately 90% of cases presenting in children younger than 5 years of age. These tumors originate where sympathetic nervous system tissue is present, within the adrenal medulla or paraspinal sympathetic ganglia, but have diverse clinical behavior depending on a variety of risk factors.

Patients with neuroblastoma are stratified into prognostic risk groups (low, intermediate, high) that determine treatment plans. Risk variables include age at diagnosis, clinical stage of disease, tumor histology, and certain molecular characteristics, including the presence of the *MYCN* oncogene. Tumor histology is categorized as favorable or unfavorable, according to the degree of tumor differentiation, the proportion of tumor stromal component, and index of cellular proliferation.[3] It is well-established that *MYCN* amplification is associated with rapid tumor progression and a poor prognosis,[4] even in the setting of other coexisting favorable factors. Loss of heterozygosity (LOH) at chromosome arms 1p and 11q frequently occurs in neuroblastoma.[5] Although 1p LOH is associated with *MYCN* amplification, 11q is usually found in tumors without this abnormality.[5] Some recent studies have shown that 1p LOH and unbalanced 11q LOH are strongly associated with outcome in patients with neuroblastoma, and both are independently predictive of worse progression-free survival (PFS) in patients with low- and intermediate-risk disease.[3] Although the use of these LOH markers in assigning treatment in patients is evolving, they may prove useful to stratify treatment.

In the early 1990s, a uniform clinical staging system based on surgical resectability and distant spread, the International Neuroblastoma Staging System, was adopted by pediatric cooperative groups (see Table 1).

Table 1. International Neuroblastoma Staging System

Stage	Description
1	Localized tumor with complete gross excision, with or without microscopic residual disease; lymph nodes negative for tumor

Stage	Description
2A	Localized tumor with incomplete gross excision; lymph nodes negative for tumor
2B	Localized tumor with or without complete gross excision, with ipsilateral lymph nodes positive for tumor
3	Unresectable unilateral tumor infiltrating across the midline, with or without regional lymph node involvement; or localized unilateral tumor with contralateral regional lymph node involvement; or midline tumor with bilateral extension by infiltration or by lymph node involvement
4	Any primary tumor with dissemination to distant lymph nodes, bone, bone marrow, liver, skin, and/or other organs, except as defined for stage 4S
4S	Localized primary tumor as defined for stage 1, 2A, or 2B, with dissemination limited to skin, liver, and/or bone marrow (marrow involvement less than 10%), limited to children younger than 1 year of age

The low-risk group includes patients younger than 1 year of age with stage 1, 2, or 4S disease with favorable histopathologic findings and no *MYCN* oncogene amplification. High-risk neuroblastoma is characterized by age older than 1 year, disseminated disease, *MYCN* oncogene amplification, and unfavorable histopathologic findings.

The International Neuroblastoma Risk Group (2009) proposed a revised staging system, which incorporated pretreatment imaging parameters instead of surgical findings (see Table 2).[6,]

Table 2. International Neuroblastoma Risk Group Staging System[6,]

Stage	Description
L1	Localized tumor not involving vital structures as defined by the list of Image-Defined Risk Factors and confined to 1 body compartment
L2	Locoregional tumor with presence of 1 or more Image-Defined Risk Factors
M	Distant metastatic disease (except stage MS)
MS	Metastatic disease in children younger than 18 months with metastases confined to skin, liver, and/or bone marrow

Treatment

In general, most patients with the low-stage disease have excellent outcomes with minimal therapy; and with International Neuroblastoma Staging System stage-1 disease, most patients can be treated by surgery alone.[7,] Most infants, even with disseminated disease, have favorable outcomes with chemotherapy and surgery.[7,]

For intermediate-risk disease, moderately intensive multiagent chemotherapy is the mainstay of therapy.[8,] Surgery is needed to obtain a diagnosis, and the extent of resection necessary to obtain an optimal outcome is not established.[9,] Patients at high-risk have historically had very low (<15%) long-term OS. Current therapy for high-risk disease typically includes an aggressive multimodal approach with chemotherapy, surgical resection, and radiotherapy.[10,]

Treatment of recurrent disease is determined by the risk group at diagnosis and the extent of disease and age of the patient at recurrence.

Ewing Sarcoma Family of Tumors

ESFT encompasses a group of tumors that share some degree of neuroglial differentiation and a characteristic underlying molecular pathogenesis (chromosomal translocation).[11,]The translocation usually involves chromosome 22 and results in fusion of the *EWS* gene with 1 of the members of the ETS (E26 transformation-specific) family of transcription factors, either FLI1 (90% to 95%) or ERG (5% to 10%).[12,]These fusion products function as oncogenic aberrant transcription factors. Detection of these fusions is considered to be specific for the ESFT and helps further validate diagnosis. Included in ESFT are "classic" Ewing sarcoma of bone, extraosseous Ewing, peripheral primitive neuroectodermal tumor, and Askin tumors (chest wall).

Most commonly diagnosed in adolescence, ESFT can be found in bone (most commonly) or soft tissue; however, the spectrum of ESFT has also been described in various organ systems. Ewing is the second most common primary malignant bone tumor.[13,] The most common primary sites are the pelvic bones, the long bones of the lower extremities, and the bones of the chest wall.

Treatment

Current therapy for Ewing sarcoma typically includes induction chemotherapy, followed by local control with surgery and/or radiotherapy (dependent on tumor size and location), followed by adjuvant chemotherapy. Multiagent chemotherapy, surgery, and radiotherapy have improved PFS rates in patients with the localized disease to 60% to 70%.[14,] The presence of metastatic disease is the most unfavorable prognostic feature, and the outcome for patients presenting with metastatic disease is poor, with 20% to 30% PFS. Other adverse prognostic factors that may categorize a patient as having "high-risk" Ewing are tumor location (e.g., patients with pelvic primaries have worse outcomes), larger tumor size, and older age of the patient. However, "high-risk" Ewing has not always been consistently defined in the literature.

Rhabdomyosarcoma

Rhabdomyosarcoma, the most common soft tissue sarcoma of childhood, shows skeletal muscle differentiation. The most common primary sites are the head and neck (e.g., parameningeal, orbital, pharyngeal), genitourinary tract, and extremities.[15,]

Treatment

Specific treatment is based on tumor location, resection, and node status, and may involve surgery, radiotherapy, and chemotherapy.[16,] Five-year survival rates for rhabdomyosarcoma increased between 1975 and 2017 from 53% to 71% in children younger than 15 years and from 30% to 52% in patients 15 to 19 years of age.[15,]

Approximately 15% of children present with metastatic disease, and despite the introduction of new drugs and intensified treatment, the 5-year survival is 20% to 30% for this "high-risk" group.[17,18,] Similarly, postrelapse mortality is very high. The prognosis of the metastatic disease is affected by tumor histology, age at diagnosis, the site of metastatic disease, and the number of metastatic sites.[15,]

Wilms Tumor

Wilms tumor is the most common primary malignant renal tumor of childhood.[19,] In the United States, Wilms tumor is staged using the National Wilms Tumor Study system, which is based on surgical evaluation before chemotherapy (see Table 3).[20,]

Table 3. National Wilms Tumor Study Staging

Stage	Description
I	(a) Tumor is limited to the kidney and completely excised; (b) The tumor was not ruptured before or during removal; (c) The vessels of the renal sinus are not involved beyond 2 mm (d) There is no residual tumor apparent beyond the margins of excision
II	(a) Tumor extends beyond the kidney but is completely excised (b) No residual tumor is apparent at or beyond the margins of excision (c) Tumor thrombus in vessels outside the kidney is stage II if the thrombus is removed en bloc with the tumor
III	Residual tumor confined to the abdomen: (a) Lymph nodes in the renal hilum, the periaortic chains, or beyond are found to contain tumor (b) Diffuse peritoneal contamination by the tumor (c) Implants are found on the peritoneal surfaces (d) Tumor extends beyond the surgical margins either microscopically or grossly (e) Tumor is not completely respectable because of local infiltration into vital structures
IV	Presence of hematogenous metastases or metastases to distant lymph nodes

Stage	Description
V	Bilateral renal involvement at the time of initial diagnosis

Adapted from Metzger and Dome (2005).[20,]

Treatment

In the United States, National Wilms Tumor Study and Children's Oncology Group protocols are based on primary resection for unilateral tumors, followed by escalating levels of chemotherapy and radiotherapy depending on tumor stage and other prognostic factors. Tumor histology, tumor stage, molecular and genetic markers (e.g., LOH at chromosome 16q), and age (>2 years) are all associated with increased risks of recurrence and death. Wilms tumors are highly sensitive to chemotherapy and radiotherapy, and current cure rates exceed 85%.[21,] Between 10% and 15% of patients with favorable histology and 50% of patients with anaplastic tumors, experience tumor progression or relapse.[21,]

Similar risk-adapted strategies are being tested for the 15% of patients who experience a relapse. Success rates after relapse range from 25% to 45%. For patients with adverse prognostic factors (histologically anaplastic tumors, relapse <6 to 12 months after nephrectomy, second or subsequent relapse, relapse within the radiation field, bone or brain metastases), the EFS rate is less than 15%.[22,]

Osteosarcoma

Osteosarcoma is a primary malignant bone tumor and the most common bone cancer in children and adolescents; it is characterized by infiltration of bone or osteoid by the tumor cells.[23,] Peak incidence occurs around puberty, most commonly in long bones such as the femur or humerus. Osteosarcomas are characterized by variants in the *TP53* tumor suppressor gene.[24,]

The prognosis of osteosarcoma has greatly improved, with 5-year survival rates increasing between 1975 and 2020 from 40% to 72% in children younger than 15 years and from 56% to 71% in 15- to 19-year olds.[24,] Prognostic factors for patients with localized disease include site and size of the primary tumor, the presence of metastases at the time of diagnosis, resection adequacy, and tumor response to neoadjuvant chemotherapy.

Treatment

For patients with recurrent osteosarcoma, the most important prognostic factor is surgical respectability. There is a 5-year survival rate of 20% to 45% in patients who had a complete resection of metastatic pulmonary tumors and a 20% survival rate for patients with metastatic tumors at other sites.[24,]

Retinoblastoma

Retinoblastoma is the most common primary tumor of the eye in children. It may occur as a heritable (25% to 30%) or nonheritable (70% to 75%) tumor.[25,] Cases may be unilateral or bilateral, with bilateral tumors almost always being the heritable type.

Treatment

Treatment options depend on the extent of disease. Retinoblastoma is usually confined to the eye, and with current therapy, has a high cure rate. However, once disease spreads beyond the eye, survival rates drop significantly; 5 year disease-free survival is reported to be less than 10% in those with the extraocular disease, and stage 4B disease (i.e., disease metastatic to the central nervous system) has been lethal in virtually all cases reported.[26,]

The strategy for nonmetastatic disease depends on the disease extent but may include focal therapies (e.g., laser photocoagulation, cryotherapy, plaque radiotherapy), intravitreal chemo-therapy, intra-arterial chemotherapy, systemic chemotherapy, enucleation, or a combination.[27,] For metastatic disease, intensive multimodal therapy with high-dose chemotherapy (HDC), with or without radiotherapy, is standard care.

Notes: Other solid tumors of childhood include germ cell tumors, which are considered in Blue Shield of California Medical Policy: Hematopoietic Cell Transplantation in the Treatment of Germ Cell Tumors. For solid tumors classified as embryonal tumors arising in the central nervous system, see Blue Shield of California Medical Policy: Hematopoietic Cell Transplantation for Central Nervous System Embryonal Tumors and Ependymoma.

Hematopoietic Cell Transplantation

HCT is a procedure in which hematopoietic stem cells are infused to restore bone marrow function in cancer patients who receive bone-marrow-toxic doses of drugs, with or without whole body radiotherapy. Hematopoietic stem cells may be obtained from the transplant recipient (autologous HCT) or a donor (allogeneic HCT). They can be harvested from bone marrow, peripheral blood, or umbilical cord blood shortly after delivery of neonates. Although cord blood is an allogeneic source, the stem cells in it are antigenically "naive" and thus are associated with a lower incidence of rejection or graft-versus-host disease.

Immunologic compatibility between infused hematopoietic stem cells and the recipient is not an issue in autologous HCT; however, immunologic compatibility between donor and patient is critical for achieving a good outcome of allogeneic HCT. Compatibility is established by typing of human leukocyte antigens using cellular, serologic, or molecular techniques. Human leukocyte antigens refer to the tissue type expressed at class I and class II loci on chromosome 6. Depending on the disease being treated, an acceptable donor (except umbilical cord blood) will match the patient at all or most human leukocyte antigens loci.

Literature Review

Evidence reviews assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life, and ability to function including benefits and harms. Every clinical condition has specific outcomes that are important to patients and managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of technology, 2 domains are examined: the relevance, and quality and credibility. To be relevant, studies must represent 1 or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

Promotion of greater diversity and inclusion in clinical research of historically marginalized groups (e.g., People of Color [African-American, Asian, Black, Latino and Native American]; LGBTQIA (Lesbian, Gay, Bisexual, Transgender, Queer, Intersex, Asexual); Women; and People with Disabilities [Physical and Invisible]) allows policy populations to be more reflective of and findings more applicable to our diverse members. While we also strive to use inclusive language related to these groups in our policies, use of gender-specific nouns (e.g., women, men, sisters, etc.) will continue when reflective of language used in publications describing study populations.

Peripheral Neuroblastoma
Single Autologous Hematopoietic Cell Transplantation

Clinical Context and Therapy Purpose
The purpose of single autologous hematopoietic cell transplantation (HCT) is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with high-risk or relapsed peripheral neuroblastoma.

The following PICO was used to select literature to inform this review.

Populations
The relevant population of interest are individuals with high-risk or relapsed peripheral neuroblastoma.

Interventions
The therapy being considered is single autologous HCT.

Comparators
Comparators of interest include chemotherapy, targeted therapy, surgery, and radiotherapy.

Outcomes
The general outcomes of interest are overall survival (OS), disease-specific survival (DSS), treatment-related mortality (TRM), and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence
Systematic Reviews
A 2013 Cochrane review evaluated high-dose chemotherapy (HDC) and autologous HCT for high-risk neuroblastomas.[28,] Reviewers identified 3 RCTs that included 739 children with high-risk neuroblastoma (Matthay et al [1999],[29,] Berthold et al [2005],[30,] and Pritchard et al [2005],[31,] detailed in the Randomized Controlled Trials section below). The review was updated in 2015 with no new studies identified, although a manuscript reporting additional follow-up data for 1 of these RCTs was noted.[32,] The primary objective was to compare the efficacy of myeloablative therapy with conventional therapy. Selected studies all used the age of 1 year as the cutoff point for pretreatment risk stratification. A statistically significant difference in event-free survival (EFS) was observed in favor of myeloablative therapy over conventional chemotherapy or no further treatment (3 studies, 739 patients; hazard ratio [HR], 0.78; 95% confidence interval [CI], 0.67 to 0.90). A statistically significant difference in OS was reported in favor of myeloablative therapy over conventional chemotherapy or no further treatment (2 studies, 360 patients; HR, 0.74; 95% CI, 0.57 to 0.98). When additional follow-up data were included in analyses, the difference in EFS remained statistically significant (3 studies, 739 patients; HR, 0.79; 95% CI, 0.70 to 0.90), but the difference in OS was no

longer statistically significant (2 studies, 360 patients; HR, 0.86; 95% CI, 0.73 to 1.01). Meta-analysis of secondary malignant disease and treatment-related death did not show any statistically significant differences between treatment groups. Data from 1 study (379 patients) showed a significantly higher incidence of renal effects, interstitial pneumonitis, and veno-occlusive disease in the myeloablative group compared with conventional chemotherapy, whereas for serious infections and sepsis, no significant differences between treatment groups were identified. No information on the quality of life was reported.

Randomized Controlled Trials

Three well-designed RCTs have assessed autologous HCT in the treatment of high-risk neuroblastoma. Matthay et al (1999) randomized 129 children with high-risk neuroblastoma to a combination of myeloablative chemotherapy, total body irradiation, and transplantation of autologous bone marrow and compared their outcomes with those of 150 children randomized to intensive nonmyeloablative chemotherapy; both groups underwent a second randomization to subsequent 13-cis-retinoic acid (cis-RA) or no further therapy.[29,] The 3-year EFS rate among patients assigned to transplantation was 43% and 27% among those assigned to continuation chemotherapy (p=.027). However, OS rates for both groups did not differ significantly, with 3-year estimates of 43% or 44% for those assigned to transplant and continued chemotherapy, respectively (p=.87).

Long-term results from this trial were reported in 2009 after a median follow-up of 7.7 years (range, 130 days to 12.8 years).[33,] The 5-year EFS rate for patients who underwent autologous transplant was 30% and 19% for those who underwent nonmyeloablative chemotherapy (p=.04). Five-year OS rates from the second randomization of patients who underwent both random assignments were 59% for autologous transplant/cis-RA, 41% for autologous transplant/no cis-RA, and, for nonmyeloablative chemotherapy, 38% and 36% with and without cis-RA. Authors concluded that myeloablative chemotherapy and autologous HCT resulted in significantly better 5-year EFS and OS rates.

Berthold et al (2005) randomized 295 patients with high-risk neuroblastoma to myeloablative therapy (melphalan, etoposide, carboplatin) plus autologous HCT or oral maintenance chemotherapy plus cyclophosphamide.[30,] The primary endpoint was EFS, with secondary endpoints of OS and treatment-related deaths. Intention-to-treat analysis showed that patients who received the myeloablative therapy had an increased 3-year EFS rate compared with the oral maintenance group (47% [95% CI, 38% to 55%] vs. 31% [95% CI, 23% to 39%]), but did not have significantly increased 3-year OS rate (62% [95% CI, 54% to 70%] vs. 53% [95% CI, 45% to 62%]; p=.088). Two patients died from therapy-related complications during induction; no patients who received oral maintenance therapy died from treatment-related toxicity, and 5 patients who received myeloablative therapy died from acute complications related to the therapy.

Pritchard et al (2005) reported the results of a randomized, multicenter trial that involved 167 children with stage 3 or 4 neuroblastoma treated with standard induction chemotherapy who then underwent surgical resection of their tumor.[31,] Sixty-nine percent (n=90) of the patients who achieved complete response (CR) or partial response (PR) to the induction chemotherapy were eligible for randomization to HDC containing melphalan plus autologous HCT or to no further treatment. Seventy-two percent (n=65) of the eligible children were randomized, with 21 surviving at the time of the analysis (median follow-up, 14.3 years). A significant difference in the 5-year EFS and OS rates were seen in children older than 1 year of age with stage 4 disease (48 children with stage 4; 5-year EFS, 33% for HDC vs. 17% for no further treatment; p=.01).

Observational Studies

The use of HCT in patients with high-risk neuroblastoma has been supported in clinical practice. For example, Proust-Houdemont et al (2016) reported on a 30-year single-center series including 215 patients with stage 4, high-risk neuroblastoma treated with HDC (busulfan) with HCT.[34,] In this cohort, 5-year EFS and OS rates were 35.1% and 40%, respectively, and improved from baseline to the end of the reporting period. In addition, Giardino et al (2020) reported results of a retrospective series of 28

patients with relapsed or refractory neuroblastoma who received metaiodobenzylguanidine and high-dose busulfan and melphalan with autologous HCT.[35,] After a median follow-up of 15.9 years, OS at 3 and 5 years was 53% and 41%, respectively, and rates of cumulative risk of progression/relapse at 3 and 5 years were 64% and 73%, respectively.

Tandem Autologous Hematopoietic Cell Transplantation

Clinical Context and Therapy Purpose

The purpose of tandem autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with high-risk or relapsed peripheral neuroblastoma.

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest are individuals with high-risk or relapsed peripheral neuroblastoma.

Interventions

The therapy being considered is tandem autologous HCT.

Comparators

Comparators of interest include chemotherapy, single autologous HCT, targeted therapy, surgery, and radiotherapy.

Outcomes

The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up at 24-, 38-, 56-, and 108-months is of interest for tandem autologous HCT to monitor relevant outcomes.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence

Randomized Controlled Trial

Park et al (2019) conducted an RCT to compare the effects of single versus tandem autologous HCT in patients with high-risk neuroblastoma.[36,] A total of 652 eligible patients were enrolled, of which 355 patients (median age at diagnosis, 36.1 months) were randomized to tandem transplant with thiotepa/cyclophosphamide followed by dose-reduced carboplatin/etoposide/melphalan (n=176) or single transplant with carboplatin/etoposide/melphalan (n=179). Three-year EFS from the time of randomization was 61.6% (95% CI, 54.3% to 68.9%) in the tandem transplant group versus 48.4% (95% CI, 41.0% to 55.7%) in the single transplant group (1-sided log-rank p=.006). The median duration of follow-up after randomization for 181 patients without an event (relapse, progression, secondary malignancy, or death from any cause) was 5.6 years (range, 0.6 to 8.9). The most commonly reported grade 3 or higher toxicities following tandem versus single transplant were mucosal (11.7% vs. 15.4%) and infectious (17.9% vs. 18.3%).

Nonrandomized Comparative Studies

Yan et al (2022) retrospectively assessed the efficacy of autologous HCT in 90 patients with high-risk neuroblastoma, and also compared the prognoses of single versus tandem transplant in these patients.[37,] The median patient age at diagnosis was 42 months (range, 11 to 97) and the median follow-up time was 29 months (range, 5 to 78). Three-year EFS and OS rates for the HCT group (n=59) compared with the non-HCT group (n=31) were 65.5% versus 41.3% (p=.023) and 77.1% versus 57.9% (p=.03), respectively. There were no statistically significant differences between the single transplant group (n=43) and the tandem transplant group (n=16) in the baseline characteristics and treatment response (p>.05). In the tandem versus single transplant group, the 3-year EFS was 51.9% compared with 73.8% (p=.44), respectively, and the 3-year OS was 71.4% compared with 83.4% (p=.73), respectively.

Sung et al (2010) reported on a retrospective analysis of the efficacy of single versus tandem autologous HCT in patients older than 1 year of age newly diagnosed with stage 4 neuroblastoma from 2000 to 2005 who were enrolled in the Korean Society of Pediatric Hematology-Oncology registry.[38,] Patients were intended to receive a single (n=70) or tandem (n=71) autologous HCT at diagnosis; 57 and 59 patients underwent single and tandem transplantation as scheduled, respectively. Between groups, patient characteristics were similar except a higher proportion in the tandem group had bone metastases. Median follow-up was 56 months (range, 24 to 88) from diagnosis. Transplant-related mortality occurred in 9 patients in the single transplant group and 8 in the tandem group (2 after the first transplant and 6 after the second). The intention-to-treat 5-year EFS rates for single and tandem were 31.3% and 51.2%, respectively (p=.03). When the survival analysis only included patients who proceeded to transplant, the probability of relapse-free survival after the first transplant was higher in the tandem group (59.1%) than the single group (41.6%; p=.099). The difference was statistically significant when the analysis focused on patients who did not achieve a CR before the first transplant (55.7% vs. 0%, p=.012). The authors concluded that tandem HCT for high-risk neuroblastoma is superior to single HCT regarding survival, particularly in patients without CR before HCT.

Ladenstein et al (2008) reported on more than 4000 transplants for primary (89%) and relapsed (11%) neuroblastoma over 28 years in 27 European countries in the European Group for Blood and Marrow Transplantation registry.[39,] Procedures included single autologous (n=2895), tandem autologous (n=455), and allogeneic HCT (n=71). Median age at the time of transplantation was 3.9 years (range, 0.3 to 62), with 77 patients older than age 18 years. Median follow-up from HCT was 9 years. Transplant-related mortality decreased over time in registry patients who only received autologous transplants. Five-year OS rates were 37% for the autologous groups (single and tandem) and 25% for the allogeneic group. Five-year OS rates for single rate and tandem autologous HCT were 38% and 33%, respectively (p=.105).

Single-Arm Studies

George et al (2006) reported on a 4-institution, single-arm clinical trial to evaluate tandem autologous HCT in pediatric patients with high-risk neuroblastoma (n=82) enrolled between 1994 and 2002.[40,] Median age at diagnosis was 35 months (range, 6 months to 18 years). Three- and 5-year OS rates were 74% (95% CI, 62% to 82%) and 64% (95% CI, 52% to 74%), respectively.

Kletzel et al (2002) reported on a single-center pilot study evaluating the outcomes for 25 consecutive newly diagnosed high-risk neuroblastoma patients and 1 with recurrent disease treated with triple-tandem autologous HCT.[41,] After stem cell rescue, patients were treated with radiotherapy to the primary site. Twenty-two of the 26 patients successfully completed induction therapy and were eligible for the triple-tandem consolidation high-dose therapy. Seventeen patients completed all 3 cycles of high-dose therapy and stem cell rescue, 2 patients completed 2 cycles, and 3 patients completed 1 cycle. One toxicity-related death occurred, and 1 patient died from complications of graft

failure. Median follow-up was 38 months, and the 3-year EFS and OS rates were 57% and 79%, respectively.

Grupp et al (2000) reported on outcomes for a phase 2 trial involving 55 children with high-risk neuroblastoma who underwent tandem autologous HCT.[42,] Five patients completed the first HCT course but not the second. There were 4 toxicity-related deaths. With a median follow-up of 24 months from diagnosis, 3-year EFS was 59%.

Case Series

In a retrospective analysis of prospectively collected data, Pasqualini et al (2016) reported on a series of 26 patients with very high-risk neuroblastoma treated with tandem autologous HCT from 2004 to 2011 at a single-center.[43,]Criteria for "very high risk" included stage 4 neuroblastoma at diagnosis or relapse, age over 1 year at diagnosis, less than a PR of metastases, and more than 3 metaiodobenzylguanidine spots after 2 lines of conventional chemotherapy in patients under 10 years old or no CR of metastases after 1 line of conventional chemotherapy in patients over 10 years old. Median age was 4.4 years (range, 1 to 15.9). Of the 26 patients, 22 were stage 4 at diagnosis; 4 patients had a stage 3 tumor at diagnosis and a metastatic relapse. Three-year EFS and OS rates after diagnosis were 37.3% (95% CI, 21.3% to 56.7%) and 69.0% (95% CI, 49.7% to 83.4%), respectively.

Kim et al (2007) retrospectively analyzed 36 patients with high-risk (stage 3 or 4) neuroblastoma who underwent a single autologous HCT (n=27) or a tandem autologous HCT (n=9) at a children's hospital in Seoul, Korea, between 1996 and 2004.[44,] Disease-free survival (DFS) of patients who underwent double HCT was similar to that of those who underwent a single autologous HCT (p=.5).

Marcus et al (2003) reported on outcomes for 52 children with stage 4 or high-risk stage 3 neuroblastoma treated with induction chemotherapy, surgical resection of the tumor when feasible, local radiotherapy, and consolidation with tandem autologous HCT.[45,] Radiotherapy was given if gross or microscopic residual disease was present before the myeloablative cycles (n=37). Of the 52 consecutively treated patients analyzed, 44 underwent both transplants, 6 underwent a single transplant, and 2 progressed during induction. The 3-year EFS was 63%, with a median follow-up of 29.5 months.

Von Allmen et al (2005) reported on a retrospective series from the same center as Marcus et al (2003), with some overlap in patients.[46,] The updated series included 76 patients with previously untreated high-risk stage 3 or 4 neuroblastoma treated with aggressive surgical resection with or without local radiotherapy followed by tandem autologous HDC and stem cell rescue. Overall EFS for the series was 56%.

Section Summary: Single Autologous and Tandem Hematopoietic Cell Transplantation for Peripheral Neuroblastoma

Randomized trials comparing single autologous HCT with conventional chemotherapy have reported EFS rates for the patients who underwent HCT ranging from 43% to 47% at 3 years and 30% at 5 years. Case series on the use of tandem autologous HCT for high-risk neuroblastoma have reported 3-year EFS rates ranging from 57% to 63%. A retrospective analysis of a registry of patients with newly diagnosed high-risk neuroblastoma reported 5-year EFS rates for single and tandem autologous HCT of 31% and 51%, respectively (p=.03). Another more recent retrospective analysis did not show statistically significant differences between single and tandem autologous HCT in treatment response, 3-year EPS, and OS. An RCT found that tandem autologous HCT resulted in statistically significantly better EFS compared with single HCT; however, since the study had a low randomization rate, the findings may not be representative of all patients with high-risk neuroblastoma.

Ewing Sarcoma Family of Tumors
Single Autologous Hematopoietic Cell Transplantation

Clinical Context and Therapy Purpose
The purpose of single autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with high-risk Ewing sarcoma/Ewing sarcoma family of tumors (ESFT).

The following PICO was used to select literature to inform this review.

Populations
The relevant population of interest are individuals with high-risk Ewing sarcoma/ESFT.

Interventions
The therapy being considered is single autologous HCT.

Comparators
Comparators of interest include chemotherapy, surgery, and radiotherapy.

Outcomes
The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence
Randomized Controlled Trials
Ladenstein et al (2010) reported on patients with primary disseminated multifocal Ewing sarcoma (PDMES) who were included in the Euro-EWING 99 trial.[47,] From 1999 to 2005, 281 patients with PDMES were enrolled in the Euro-EWING 99 R3 study; the Euro-EWING 99 committee stopped enrollment to this group and released the data. The median age was 16.2 years (range, 0.4 to 49). Patients with isolated lung metastases were not part of the analysis. The recommended treatment consisted of induction chemotherapy, HDC, autologous HCT, and local treatment to the primary tumor (surgery and/or radiotherapy or neither). Induction therapy was completed by 250 (89%) patients. One hundred sixty-nine (60%) of the patients proceeded to HCT. One patient died during induction therapy from sepsis. HDC TRM consisted of 3 patients dying within the first 100 days after high-dose therapy, 1 from acute respiratory distress syndrome and 2 from severe veno-occlusive disease and septicemia; late deaths included 3 patients who died 1 to 1.5 years after high-dose therapy. After a median follow-up of 3.8 years, the estimated 3-year EFS and OS for all 281 patients were 27% and 34%, respectively. The international Ewing 2008 trial succeeded the Euro-EWING 99 study in some countries.[48,] The Ewing 2008 trial contained an R2Pulm arm for patients with isolated pulmonary metastases (Tables 4 and 5). The primary objective in R2Pulm was to evaluate whether consolidation with HDC plus autologous HCT (n=144) improved EFS compared with consolidation with

standard chemotherapy plus whole lung irradiation (n=143). Dirksen et al (2019) reported on the results of this trial, which found no statistically significant difference in EFS between treatment groups. Nine patients died in the HDC plus autologous HCT group (6 of these deaths were treatment-related and 3 were either due to secondary malignancy, another cause, or unknown cause), and 2 died after standard chemotherapy plus whole lung irradiation (1 death was treatment-related and 1 was due to another cause). Severe acute toxicities were also more prevalent in the group who received HDC plus autologous HCT.

Table 4. Summary of Key RCT Characteristics

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					Active	Comparator
Dirksen (2019); R2Pulm[48,]	US, EU	144	December 2015 to February 2020	N=267 patients <50 years of age	n=144; HDC plus autologous HCT	n=143; 7 courses of standard chemotherapy plus whole lung irradiation

HCT: hematopoietic cell transplantation; HDC: high-dose chemotherapy; RCT: randomized controlled trial.

Table 5. Summary of Key RCT Results

Study; Trial	EFS[1] (3 years)	EFS[1] (8 years)	Mortality
Dirksen (2019); R2Pulm[48,]			
N	287	287	287
HDC plus autologous HCT	56.6%	52.9%	9/144
Standard chemotherapy plus whole lung irradiation	50.6%	43.1%	2/143
Adjusted HR (95% CI)		0.81 (0.58 to 1.12)	

CI: confidence interval; EFS: event-free survival; HCT: hematopoietic cell transplantation; HDC: high-dose chemotherapy; HR: hazard ratio; RCT: randomized controlled trial.
[1] Intention-to-treat analysis

Tables 6 and 7 summarize study relevance, conduct, and design limitations.

Table 6. Study Relevance Limitations

Study; Trial	Population[a]	Intervention[b]	Comparator[c]	Outcomes[d]	Duration of Follow-up[e]
Dirksen (2019); R2Pulm[48,]	4: Only included patients with Ewing sarcoma and lung metastases				

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.
[a] Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4, Enrolled populations do not reflect relevant diversity; 5. Other.
[b] Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5: Other.
[c] Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.
[d] Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.
[e] Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

Table 7. Study Design and Conduct Limitations

Study; Trial	Allocation[a]	Blinding[b]	Selective Reporting[c]	Data Completeness[d]	Power[e]	Statistical[f]
Dirksen (2019); R2Pulm[48,]		1,2: Open-label study			4. Recruitment was stopped before the estimated sample	

Study; Trial	Allocation[a]	Blinding[b]	Selective Reporting[c]	Data Completeness[d]	Power[e]	Statistical[f]
					size target was reached due of low accrual	

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.
[a] Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4. Inadequate control for selection bias; 5. Other.
[b] Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.
[c] Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.
[d] Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.
[e] Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.
[f] Statistical key: 1. Analysis is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other.

Single-Arm Studies

Subsequently, Meyers et al (2001) reported on a prospective study with autologous HCT in 32 patients with newly diagnosed Ewing sarcoma metastatic to bone and/or bone marrow. Induction therapy consisted of 5 cycles of cyclophosphamide-doxorubicin-vincristine, alternating with ifosfamide-etoposide.[49,] Twenty-three patients proceeded to the consolidation phase with melphalan, etoposide, total body irradiation, and autologous HCT (of the 9 patients who did not proceed, 2 were secondary to toxicity and 4 to progressive disease). Three patients died during the HDC phase. Two-year EFS for all eligible patients was 20% and 24% of the 29 patients who received the high-dose consolidation therapy. Trialists concluded that consolidation with HDC, total body irradiation, and autologous stem cell support failed to improve EFS for this cohort of patients compared with a similar group of patients treated with conventional therapy. Authors noted their findings differed from some previous studies and that the previous studies were limited by the inclusion of heterogeneous patient populations. They concluded that future trials of autologous HCT must be conducted prospectively, identify a group at high-risk for failure, and enroll all patients in the study at the same point in therapy.

Gardner et al (2008) reported on the results of 116 patients with Ewing sarcoma who underwent autologous HCT (80 as first-line therapy, 36 for recurrent disease) between 1989 and 2000.[50,] Five-year rates of progression-free survival (PFS) in patients who received HCT as first-line therapy were 49% (95% CI, 30% to 69%) for those with localized disease at diagnosis and 34% (95% CI, 22% to 47%) for those with metastatic disease at diagnosis. For the population with localized disease at diagnosis and recurrent disease, the 5-year probability of PFS was 14% (95% CI, 3% to 30%). The authors concluded that PFS rates after autologous HCT were comparable with rates seen in patients with similar disease characteristics treated with conventional therapy.

Case series

During the 1980s and 1990s, several small series, case reports, and a report from the European Bone Marrow Transplant Registry suggested that autologous HCT could improve outcomes for patients with high-risk ESFT.[51,] These early results supported the use of HCT for high-risk ESFT.

Tandem Autologous Hematopoietic Cell Transplantation

Clinical Context and Therapy Purpose

The purpose of tandem autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with high-risk Ewing sarcoma/ESFT.

The following PICO was used to select literature to inform this review.

Populations
The relevant population of interest are individuals with high-risk Ewing sarcoma/ESFT.

Interventions
The therapy being considered is tandem autologous HCT.

Comparators
Comparators of interest include chemotherapy, single autologous HCT, surgery, and radiotherapy.

Outcomes
The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence
Case Series
Loschi et al (2015) reported on a series of 18 patients with PDMES under age 25 years treated with tandem HCT at a single institution from 2002 to 2009.[52,] Of the 18 patients with PDMES planned for tandem HCT, 15 (83%) received the first HCT, and 13 (72%) received the full-tandem HCT program, due to progressive disease before stem cell harvest could be obtained. Eleven patients had no disease progression by the end of the HCT program, but 9 of the 11 had relapsed, at a median delay of 6.2 months (range, 2.5 to 14.1). Median EFS and OS rates were 13.5 and 17.3 months, respectively.

Section Summary: Single Autologous and Tandem Hematopoietic Cell Transplantation for Ewing Sarcoma Family of Tumors
Studies of HCT in patients with ESFT are characterized by small numbers of patients, and comparisons across studies were difficult for several reasons. Within each report, patients could have received a variety of chemotherapeutic regimens, and many studies did not share the same patient eligibility criteria (and in some, the definition of high-risk included patients with criteria that did not result in inferior prognosis). Also, some studies used allogeneic HCT. The risk-adjusted system used in Euro-EWING 99 may allow the best selection of patients appropriate for treatment. The international Ewing 2008 trial succeeded the Euro-EWING 99 study in some countries. The Ewing 2008 trial contained an R2Pulm arm for patients with Ewing sarcoma and pulmonary and/or pleural metastases. The R2PulmRCT compared consolidation with HDC plus autologous HCT to standard chemotherapy plus whole lung irradiation and did not find a significant EFS advantage with either treatment.

Rhabdomyosarcoma

Clinical Context and Therapy Purpose

The purpose of single autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with rhabdomyosarcoma (RMS).

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest are individuals with RMS.

Interventions

The therapy being considered is single autologous HCT.

Comparators

Comparators of interest include chemotherapy, surgery, and radiotherapy.

Outcomes

The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence

Systematic Review

Weigel et al (2001) reviewed and summarized published evidence on the role of autologous HCT in the treatment of metastatic or recurrent RMS from 22 studies (N=389 patients).[53,] Based on all of the evidence analyzing EFS and OS rates, the authors concluded there was no significant advantage in undergoing HDC with HCT in patients with relapsed or refractory high-risk RMS.

Nonrandomized Comparative Studies

McDowell et al (2010) reported on the results of the International Society of Paediatric Oncology study MMT-98; pediatric patients from 48 centers with metastatic RMS entered into the study from 1998 to 2005.[54,] A total of 146 patients enrolled (age range, 6 months to 18 years). Patients were risk-stratified and treated accordingly. One hundred one patients were stratified as poor-risk (poor-risk group), defined as being older than 10 years of age or having bone marrow or bone metastases. Planned therapy for the poor-risk group was induction therapy, sequential HDC, peripheral blood autologous HCT, and maintenance therapy. Seventy-nine (78.2%) of the 101 poor-risk patients underwent the high-dose therapy, after which 67.1% achieved a PR or CR. Sixty-seven of the 101 poor-risk patients received local treatment : 37 received radiotherapy alone, 10 received surgery alone, and 20 received both modalities. No treatment-related deaths were reported in the poor-risk group. Three- and 5-year EFS rates for the poor-risk group were 16.5% and 14.9%, respectively, with 3- and 5-year OS rates of 23.7% and 17.9%, respectively (HR, 2.46; 95% CI, 1.51 to 4.03; p<.001).

Klingebiel et al (2008) prospectively compared the efficacy of 2 HDC treatments followed by autologous stem cell rescue with an oral maintenance treatment (OMT) in 96 children with stage 4 soft tissue sarcoma (88 of whom had RMS).[55,] Five-year OS probability for the whole group was 0.52 (standard deviation [SD], 0.14) for the patients who received OMT (n=51) and 0.27 (SD, 0.13) for the transplant group (n=45; p=.03). For the patients with RMS, 5-year OS probability was 0.52 (SD, 0.16) with OMT and 0.15 (SD, 0.12) with transplant (p=.001). The authors concluded that transplant failed to improve prognosis in metastatic soft tissue sarcoma but that OMT could be a promising alternative.

Carli et al (1999) conducted a prospective nonrandomized study of 52 patients with metastatic RMS, who were in CR after induction therapy and subsequently received HDC (megatherapy) and autologous HCT, and compared them with 44 patients who were in remission after induction therapy who subsequently received conventional chemotherapy.[56,] No significant differences existed between groups (i.e., clinical characteristics, induction chemotherapy received, sites of primary tumor, histologic subtype, age, presence/extent of metastases). Three-year EFS and OS rates were 29.7% and 40%, respectively, for the autologous HCT group and 19.2% and 27.7%, respectively, for the chemotherapy group. Differences were not statistically significant for EFS (p=.3) or OS (p=.2). Median time to relapse after chemotherapy was 168 days for the autologous HCT group and 104 days for the standard chemotherapy group (p=.05). Although the use of autologous HCT delayed time to relapse, there was no clear survival benefit compared with conventional chemotherapy.

Section Summary: Rhabdomyosarcoma

Autologous HCT has been evaluated in a limited number of patients with high-risk RMS (stage 4 or relapsed) in whom CR was achieved after standard induction therapy. The evidence is relatively scarce, due in part to the rarity of the condition. The role of stem cell transplantation n any type for this cancer has not been established.

Wilms Tumor

Clinical Context and Therapy Purpose

The purpose of single autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with Wilms tumor.

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest are individuals with Wilms tumor.

Interventions

The therapy being considered is single autologous HCT.

Comparators

Comparators of interest include chemotherapy, surgery, and radiotherapy.

Outcomes

The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;

- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence

Meta-analysis

A 2010 individual patient data meta-analysis reported on the efficacy of autologous HCT in recurrent Wilms tumor for studies published between 1984 and 2008 that reported survival data.[57,] Six studies were included (N=100 patients).[21,58,59,60,61,62,] Patient characteristics and treatment methods were similar across studies, although there was variation in the preparative regimens used. Patients were between the ages of 11 months and 16 years and had similar primary tumor stage, relapse location, and time to relapse. The 4-year OS rate among the 100 patients was 54.1% (95% CI, 42.8% to 64.1%), and the 4-year EFS rate (based on 79 patients) was 50.0% (95% CI, 37.9% to 60.9%). In multivariate analysis, site of relapse and histology were important predictors for survival; patients who did not have a lung-only relapse were at approximately 3 times higher risk of death or recurrence (HR, 3.5) than patients who relapsed in the lungs only (HR, 2.4), and the patients with unfavorable histology had approximately twice the risk of death compared with those with favorable histology. For all 6 studies, reviewers compared the survival rates for patients who received autologous HCT with patients who received conventional chemotherapy. In general, the chemotherapy-treated patients had similar or improved 4-year survival rates compared with the HCT group; however, there was a suggestion that patients with lung-only stage 3 and 4 relapses could benefit from autologous HCT; they had a 21.7% survival advantage over chemotherapy (however, the CI ranges were very wide): 4-year OS rates for the stage 3 and 4 patients with lung-only relapse treated with HCT were 74.5% (95% CI, 51.7% to 87.7%) and 52.8% (95% CI, 29.7% to 71.5%) for chemotherapy.

Retrospective Studies

Delafoy et al (2022) published a retrospective analysis describing the outcomes of 54 patients with Wilms tumor in France who received HDC plus autologous HCT as first-line treatment or following disease recurrence between 2000 and 2016.[63,] The 5-year estimates for EFS and OS in patients receiving first-line treatment were 54% (95% CI, 32% to 76%) and 62% (95% CI, 31% to 82%), respectively. The 5-year estimates for EFS and OS in patients receiving treatment following disease recurrence were 57% (95% CI, 39% to 71%) and 69% (95% CI, 52% to 81%), respectively. Treatment-related death occurred in 3 patients.

Malogolowkin et al (2017) published a retrospective analysis describing the outcomes of 253 patients with relapsed Wilms tumor who received HDC followed by autologous HCT between 1990 and 2013 that were reported to the Center for International Blood and Marrow Transplant Research.[64,] The 5-year estimates for EFS and OS were 36% (95% CI, 29% to 43%) and 45% (95 CI, 38% to 51%), respectively. Relapse of primary disease was the cause of death in 81% of the population. EFS, OS, relapse, and transplant-related mortality showed no significant differences when broken down by disease status at transplant, time from diagnosis to transplant, year of transplant, or conditioning regimen. The data suggest that HDC followed by autologous HCT for relapsed Wilms tumor is well-tolerated, and outcomes are similar to those reported in the literature. The greatest limitation of the study is its retrospective design (registry-based analyses) and that the data originated from basic forms, and thus, did not include information on histology, site of metastases, stage of disease, genetic syndrome, tumor spillage, and radiation.

Section Summary: Wilms Tumor

The evidence on the use of autologous HCT for high-risk Wilms tumor consists of retrospective studies and an individual patient data meta-analysis. For some subgroups, particularly patients with lung-only stage 3 and 4 relapses,some analyses have suggested that HCT could be associated with a survival benefit.

Osteosarcoma

Clinical Context and Therapy Purpose

The purpose of single autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with osteosarcoma.

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest are individuals with osteosarcoma.

Interventions

The therapy being considered is single autologous HCT.

Comparators

Comparators of interest include chemotherapy, surgery, and radiotherapy.

Outcomes

The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence

Prospective and Retrospective Studies

Hong et al (2022) retrospectively evaluated 113 patients with nonmetastatic osteosarcoma.[65,] The median patient age at diagnosis was 12.6 years (range, 5.0 to 20.3). All patients received neoadjuvant chemotherapy, which was continued when the postoperative necrosis rate was more than 90% (good response), whereas most cases with less than 90% (poor response) were changed to chemotherapy (either adjuvant conventional chemotherapy, or HDC [melphalan/etoposide/carboplatin] with autologous HCT). In patients with poor response (n=44), the 5-year EFS rates of the HDC plus HCT group (n=24) compared with conventional chemotherapy (n=20) were 78.6% (95% CI, 61.9% to 95.3%) and 53.6% (95% CI, 31.1% to 76.1%; p=.065), respectively, and the 5-year OS rates were 100% and 76.9% (95% CI, 56.7% to 97.1%; p=.024), respectively. A limitation of the study is that it was a retrospective analysis that included patients who received heterogeneous chemotherapies. The study authors also acknowledged that previous studies, including the Venkatramani et al (2016) prospective study summarized below,[66,] did not find improved outcomes with HDC with HCT. However, this study is different from previous studies in the regimen used (melphalan/etoposide/carboplatin) and in analyzing only patients with nonmetastatic osteosarcoma who showed low-degree necrosis following neoadjuvant chemotherapy.

Venkatramani et al (2016) reported on outcomes from a protocol in which patients with newly diagnosed, biopsy-proven high-grade osteosarcoma with less than 90% tumor necrosis after

preoperative chemotherapy were treated with 3 courses of HDC plus autologous HCT.[66,] The single-arm study enrolled 52 patients with localized osteosarcoma, most commonly of the femur (52%), from 1999 to 2006 who underwent definitive surgery; 6 patients withdrew prior to surgery, and 6 after surgery. Under the study's initial protocol, those with less than 90% tumor necrosis were intended for HCT following HDC with melphalan and cyclophosphamide, and those with good tumor response were allocated to standard chemotherapy. However, after the first 18 patients received HCT, an interim analysis showed a 2-year EFS rate of 41%, which was less than the objective of 75% EFS compared with historical data of 55% by treating 48 patients with nonmetastatic disease who showed less than 90% necrosis following preoperative chemotherapy. Subsequently, all patients were enrolled in the standard therapy arm. Forty patients were evaluable after a median follow-up of 39 months. The 5-year EFS and OS rates were 62% (95% CI, 36% to 80%) and 74% (95% CI, 44% to 90%), respectively, for patients treated in the standard chemotherapy arm. The 5-year EFS and OS rates were 28% (95% CI, 10% to 49%) and 48% (95% CI, 23% to 69%), respectively, for patients treated in the HCT arm.

Case Series

Hong et al (2015) reported on a series of 19 patients with high-risk osteosarcoma treated with autologous HCT at a single-center from 2006 to 2013.[67,] Median age at diagnosis was 11.8 years (range, 5.4 to 5.7). The indications for HCT were tumor necrosis less than 90% (n=8); initial metastasis (n=2); relapse (n=2); or a combination of tumor necrosis less than 90%, initial metastasis, and/or progression (n=6). At a mean follow-up of 31 months (range, 1 to 91), the OS rate was 78.3%, and the EFS rate was 67.4%.

Additional, small case series and case reports have examined the use of autologous HCT in osteosarcoma.[68,69,] Autologous HCT has been successful in inducing short-lasting remissions but has not shown an increase in survival.

Section Summary: Osteosarcoma

The evidence on the use of autologous HCT for treatment of osteosarcoma is limited to case series, a prospective single-arm study, and a retrospective study. An interim analysis of the single-arm study showed that patients receiving autologous HCT were experiencing lower EFS rates than historical controls, resulting in all patients enrolling in the standard of care chemotherapy arm for the remainder of the study. Conversely, a retrospective study found favorable survival outcomes with HDC plus autologous HCT in patients with nonmetastatic osteosarcoma with low-degree necrosis after neoadjuvant chemotherapy.

Retinoblastoma

Localized Retinoblastoma

Clinical Context and Therapy Purpose

The purpose of single autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with localized retinoblastoma.

The following PICO was used to select literature to inform this review.

Populations

The relevant population of interest are individuals with localized retinoblastoma.

Interventions

The therapy being considered is single autologous HCT.

Comparators

Comparators of interest include laser photocoagulation, cryotherapy, chemotherapy (local or systemic), surgery, and radiotherapy.

Outcomes
The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.
- Studies with duplicative or overlapping populations were excluded.

Review of Evidence
No studies focusing on autologous HCT for patients with localized retinoblastoma were identified in literature searches.

Metastatic Retinoblastoma
Clinical Context and Therapy Purpose
The purpose of single autologous HCT is to provide a treatment option that is an alternative to or an improvement on existing therapies in patients with metastatic retinoblastoma.

The following PICO was used to select literature to inform this review.

Populations
The relevant population of interest are individuals with metastatic retinoblastoma.

Interventions
The therapy being considered is single autologous HCT.

Comparators
Comparators of interest include chemotherapy, surgery, and radiotherapy.

Outcomes
The general outcomes of interest are OS, DSS, TRM, and treatment-related morbidity.

Follow-up includes the immediate and 12-month posttransplant period to monitor for engraftment and other relevant outcomes. Follow-up will continue to be life-long depending on the success of single autologous HCT.

Study Selection Criteria
Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies.
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought.

- Studies with duplicative or overlapping populations were excluded.

Review of Evidence

Prospective and Retrospective Studies

A prospective, international trial assessed the effectiveness of intensive multimodality therapy in patients aged 10 years and younger with extraocular retinoblastoma.[70,] Patients with stage 2 or 3 (locoregional) disease received 4 cycles of chemotherapy and radiation therapy. Patients with stage 4A or 4B (metastatic or trilateral) disease received 4 cycles of chemotherapy; those with at least a PR then received 1 cycle of HDC with autologous HCT. The median follow-up was 7.3 years. One-year EFS was 88.1% (90% CI, 66.6% to 96.2%) for stage 2 or 3 disease (n=19), 82.6% (90% CI, 61.0% to 92.9%) for stage 4A disease (n=18), and 28.3% (90% CI, 12.7% to 46.2%) for stage 4B disease (n=20). Recurrences occurred in 2 patients with stage 4A disease at 5 and 9 months, and 10 patients with stage 4B disease at a median of 6 months; all recurrences were in the central nervous system (CNS). The authors concluded that more effective therapy is needed for stage 4B disease (patients with CNS involvement).

Farouk et al (2022) performed a retrospective analysis of 24 patients with stage 4A metastatic retinoblastoma who underwent HDC plus autologous HCT.[71,] All patients experienced hematopoietic recovery post HCT. The median age at diagnosis of stage 4A retinoblastoma and HCT was 2 years (range, 0.1 to 7.4) and 3.7 years (range, 2.3 to 9.8), respectively. The median follow-up time from HCT was 6.3 years (range, 0.4 to 27.7). Kaplan-Meier estimates of 5-year and 10-year OS were 81% ± 8.6% and 59.3% ± 12.4%, respectively, with early deaths due to recurrent retinoblastoma (n=4) and late deaths due to subsequent malignant neoplasms. The authors concluded that intensive multimodality therapy including HDC plus autologous HCT is curative in most patients with stage 4A retinoblastoma.

Case Series

Most studies of autologous HCT for metastatic retinoblastoma have been very small series or case reports.[72,73,74,75,] More recently, Dunkel et al (2010) reported on outcomes for 15 consecutive patients with stage 4A metastatic retinoblastoma who presented between 1993 and 2006 and were treated with HDC and autologous HCT.[76,] Twelve patients had unilateral retinoblastoma, and 3 had bilateral disease. Metastatic disease was not detected at diagnosis but became clinically evident at a median of 6 months (range, 1 to 82) postenucleation. Patients had metastatic disease to bone marrow (n=14), bone (n=10), the orbit (n=9), and/or the liver (n=4). Two patients progressed before HCT and died. Thirteen patients underwent HCT, and 10 are retinoblastoma-free in first remission at a median follow-up of 103 months (range, 34 to 202). Three patients experienced recurrence 14 to 20 months postdiagnosis of metastatic disease, (2 in the CNS , 1 in the mandible), and all died of their disease. Five-year retinoblastoma-free survival and EFS rates were 67% (95% CI, 38% to 85%) and 59% (95% CI, 31% to 79%), respectively. Six of the 10 patients who survived received radiotherapy. Three patients developed secondary osteosarcoma at 4, 9, and 14 years postdiagnosis of metastatic disease, 2 in previously irradiated fields, and 1 in a nonirradiated field. The authors concluded that HCT was curative for most patients treated in their study with stage 4A retinoblastoma.

Dunkel et al (2010) also reported on outcomes for 8 patients diagnosed with stage 4B retinoblastoma between 2000 and 2006 treated with the intention of autologous HCT.[26,] Seven patients had leptomeningeal disease and 1 had only direct extension to the CNS via the optic nerve. At the time of diagnosis of intraocular retinoblastoma, 3 patients already had stage 4B disease; the other 5 patients developed metastatic disease at a median of 12 months (range, 3 to 69). Two patients progressed before HCT, and 1 patient died due to toxicity during induction chemotherapy. Of the 5 patients who underwent HCT, 2 were event-free at 40 and 101 months. One of the event-free survivors received radiotherapy (external-beam plus intrathecal radioimmunotherapy), and the other did not receive any radiotherapy. Three patients had tumor recurrence at 3, 7, and 10 months post-HCT. The authors concluded that HCT could be beneficial for some patients with stage 4B

retinoblastoma, but longer follow-up would be necessary to determine whether it is curative in this population.

Section Summary: Localized and Metastatic Retinoblastoma

There is a lack of evidence evaluating the use of autologous HCT for localized retinoblastoma. The role of stem cell transplantation has not been established in the therapy of patients with localized retinoblastoma.

The results have been promising regarding prolonging EFS and OS in patients with metastatic retinoblastoma, particularly those without CNS involvement (stage 4A). Given that clinical prognosis is very poor for patients with metastases, results showing the survival of some patients for 3 or more years after HCT might provide evidence to demonstrate a benefit in survival.

Comparative Effectiveness Review

The Blue Cross and Blue Shield Association (2012) prepared a comparative effectiveness review on the use of HCT in the pediatric population for the Agency for Healthcare Research and Quality.[77,] The following conclusions were offered:

- Neuroblastoma: The body of evidence on OS with tandem HCT compared with single HCT for the treatment of high-risk neuroblastoma was insufficient to draw conclusions.
- ESFT: The low-strength evidence on OS suggested no benefit with single HCT compared with conventional therapy for the treatment of high-risk ESFT.
    - The body of evidence on OS with tandem HCT compared with single HCT for the treatment of high-risk ESFT and OS was insufficient to draw conclusions.
- RMS: The moderate-strength evidence on OS suggested no benefit with single HCT compared with conventional therapy for the treatment of high-risk metastatic RMS.
    - The body of evidence on OS with single HCT compared with conventional therapy for the treatment of high-risk RMS of mixed tumor type was insufficient to draw conclusions.
    - The body of evidence on OS with single HCT compared with conventional therapy for the treatment of congenital alveolar RMS, cranial parameningeal RMS with metastasis or the use of allogeneic transplantation for metastatic RMS was insufficient to draw conclusions.
- Wilms tumor: The low-strength evidence on OS suggested no benefit with single HCT compared with conventional therapy for the treatment of high-risk relapsed Wilms tumor.
- Osteosarcoma was not addressed.
- Retinoblastoma: The low-strength evidence on OS suggested no benefit with single HCT compared with conventional therapy for the treatment of extraocular retinoblastoma with CNS involvement.
    - The body of evidence on OS with single HCT compared with conventional therapy for the treatment of extraocular retinoblastoma without CNS involvement was insufficient to draw conclusions.
    - The body of evidence on OS with single HCT compared with conventional therapy for the treatment of trilateral retinoblastoma without CNS involvement was insufficient to draw conclusions.

Supplemental Information

The purpose of the following information is to provide reference material. Inclusion does not imply endorsement or alignment with the evidence review conclusions.

Clinical Input From Physician Specialty Societies and Academic Medical Centers

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

2017 Input

Clinical input was sought to help determine whether the use of autologous hematopoietic cell transplantation (HCT) for individuals with advanced-stage Wilms tumor, osteosarcoma, and retinoblastoma would provide a clinically meaningful improvement in net health outcome and whether the use is consistent with generally accepted medical practice. In response to requests, clinical input was received from 2 respondents, including 2 physicians with academic medical center affiliation.

For individuals who have advanced-stage Wilms tumor who receive autologous HCT, clinical input does not support a clinically meaningful improvement in net health outcome and does not indicate this use is consistent with generally accepted medical practice.

For individuals who have osteosarcoma who receive autologous HCT, clinical input does not support a clinically meaningful improvement in net health outcome and does not indicate this use is consistent with generally accepted medical practice.

For individuals who have metastatic retinoblastoma who receive autologous HCT, clinical input supports this use provides a clinically meaningful improvement in net health outcome and indicates this use is consistent with generally accepted medical practice.

Further details from clinical input are included in the Appendix.

2011 Input

Clinical input was sought to help determine whether the use of single autologous HCT for individuals with high-risk Ewing sarcoma would provide a clinically meaningful improvement in net health outcome and whether the use is consistent with generally accepted medical practice. In response to requests, clinical input was received from 3 academic medical centers and 2 Blue Distinction Centers for Transplants.

For individuals who have high-risk Ewing sarcoma who receive single autologous HCT, clinical input supports this use provides a clinically meaningful improvement in net health outcome and indicates this use is consistent with generally accepted medical practice. One reviewer did not consider autologous HCT for low- to intermediate-risk Ewing sarcoma investigational but did state that the results of the Euro-EWING's phase 3 trial were awaited.

Practice Guidelines and Position Statements

Guidelines or position statements will be considered for inclusion in 'Supplemental Information' if they were issued by, or jointly by, a US professional society, an international society with US representation, or National Institute for Health and Care Excellence (NICE). Priority will be given to guidelines that are informed by a systematic review, include strength of evidence ratings, and include a description of management of conflict of interest.

American Society for Transplantation and Cellular Therapy

In 2020, the American Society for Transplantation and Cellular Therapy published consensus guidelines for clinically appropriate indications for HCT based on best prevailing evidence.[78,] Indications for HCT in pediatric patients with the solid tumors types addressed in this review are outlined in Table 8.

Table 8. Indications for Hematopoietic Cell Transplant in Pediatric Patients with Solid Tumors

Indication and Disease Status	Allogeneic HCT[a]	Autologous HCT[a]
Ewing sarcoma, high risk or relapse	D	S
Soft tissue sarcoma, high risk or relapse	D	D
Neuroblastoma, high risk or relapse	D	S[b]
Wilms tumor, relapse	N	C
Osteosarcoma, high risk	N	C

Adapted from Kanate et al (2020).[78,]
HCT: hematopoietic cell transplantation.
[a] "Standard of care (S): This category includes indications that are well defined and are generally supported by evidence in the form of high quality clinical trials and/or observational studies (e.g., through CIBMTR or EBMT)." "Standard of care, clinical evidence available (C): This category includes indications for which large clinical trials and observational studies are not available. However, HCT/immune effector cell therapy (IECT) has been shown to be an effective therapy with acceptable risk of morbidity and mortality in sufficiently large single- or multi-center cohort studies. HCT/IECT can be considered as a treatment option for individual patients after careful evaluation of risks and benefits. As more evidence becomes available, some indications may be reclassified as 'Standard of Care'." "Developmental; (D): Developmental indications include diseases where pre-clinical and/or early phase clinical studies show HCT/IECT to be a promising treatment option. HCT/IECT is best pursued for these indications as part of a clinical trial. As more evidence becomes available, some indications may be reclassified as 'Standard of Care, Clinical Evidence Available' or 'Standard of Care'." "Not generally recommended (N): HCT/IECTis not currently recommended for these indications where evidence do not support the routine use of HCT/IECT. However, this recommendation does not preclude investigation of HCT/IECT as a potential treatment and may be pursued for these indications within the context of a clinical trial.
[b] Tandem autologous HCT recommended.

National Comprehensive Cancer Network

Current National Comprehensive Cancer Network (NCCN) guidelines or comments on HCT related to the cancers addressed in this review are summarized in Table 9. Other tumor types are not addressed in Network guidelines.

Table 9. National Comprehensive Cancer Network Guidelines

Guideline	Tumor Type	Year	NCCN Comments
Bone cancer[79,]	Osteosarcoma	v1.2024	"The safety and efficacy of HDT/HCT in patients with locally advanced, metastatic, or relapsed osteosarcoma have also been evaluated. In the Italian Sarcoma Group study, treatment with carboplatin and etoposide was followed by stem cell rescue, combined with surgery-induced complete response in chemosensitive disease. Transplant-related mortality was 3.1%. The 3-year OS and DFS rates were 20% and 12%, respectively. The efficacy of this approach in patients with high-risk disease is yet to be determined in prospective randomized studies."
Bone cancer[79,]	Ewing sarcoma	v1.2024	"High dose therapy followed by hematopoietic cell transplant (HDT/HCT) has been evaluated in patients with localized as well as metastatic disease. HDT/HCT has been associated with potential survival benefit in patients with non-metastatic disease. However, studies that have evaluated HDT/HCT in patients with primary metastatic disease have shown conflicting results.... HDT/HCT has been associated with improved long-term survival in patients with relapsed or progressive Ewing sarcoma in small, single-institution studies. The role of this approach is yet to be determined in prospective randomized studies."
Soft tissue sarcoma[80,]	Rhabdomyosarcoma	v2.2023	HCT not addressed
Wilms tumor (nephroblastoma)[81,]	Wilms tumor	v1.2023	HCT not addressed

DFS: disease-free survival; HCT: hematopoietic cell transplantation; HDT: high-dose therapy; NCCN: National Comprehensive Cancer Network; OS: overall survival.

U.S. Preventive Services Task Force Recommendations
Not applicable.

Medicare National Coverage
There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

Ongoing and Unpublished Clinical Trials
Some currently ongoing trials that might influence this policy are listed in Table 10.

Table 10. Summary of Key Trials

NCT No.	Trial Name	Planned Enrollment	Completion Date
Combined solid tumor			
NCT00638898	Pilot Study of High-Dose Chemotherapy With Busulfan, Melphalan, and Topotecan Followed by Autologous Hematopoietic Stem Cell Transplant in Advanced Stage and Recurrent Tumors	25	Dec 2023 (ongoing)
NCT01505569	Alkylator-Intense Conditioning Followed by Autologous Transplantation for Patients With High Risk or Relapsed Solid or CNS Tumors	20	Mar 2025 (recruiting)
NCT04530487	A Pilot Study of Allogeneic Hematopoietic Stem Cell Transplantation for Pediatric and Adolescent-Young Adults Patients With High Risk Solid Tumors	40	May 2025 (recruiting)
Peripheral neuroblastoma			
NCT01526603	High Dose Chemotherapy and Autologous Peripheral Blood Stem Cell (PBSC) Rescue for Neuroblastoma: Standard of Care Considerations	20	Feb 2024 (recruiting)
NCT02605421	Tandem Myeloablative Consolidation Therapy and Autologous Stem Cell Rescue for High-Risk Neuroblastoma	12	Jul 2025 (recruiting)
NCT01704716	High Risk Neuroblastoma Study 1 of SIOP-Europe (SIOPEN)	3300	Sep 2026 (recruiting)
Ewing sarcoma			
NCT03011528	CombinaiR3 - First-line Treatment of Ewing Tumours with Primary Extrapulmonary Dissemination in Patients from 2 to 50 Years	45	Feb 2024 (ongoing)

NCT: national clinical trial.

Appendix 1

2017 Clinical Input
Objective
Clinical input was sought to help determine whether the use of autologous HCT for individuals with advanced-stage Wilms tumor, osteosarcoma, and retinoblastoma would provide a clinically meaningful improvement in net health outcome and whether the use is consistent with generally accepted medical practice. In response to requests, clinical input was received from 2 respondents, including 2 physicians with academic medical center affiliation.

Respondents
Clinical input was provided by the following specialty societies and physician members identified by a specialty society or clinical health system:

Appendix Table 1. Respondent Profile

No.	Name	Degree	Organization	Clinical Specialty	Board Certification and Fellowship Training
Identified by American Society for Blood and Marrow Transplant					
1	Kitko, Carrie L.	MD	Vanderbilt University Medical Center	Pediatric Hematology/Oncology, BMT	Pediatric hematology/oncology; Fellowship training at University of Michigan
Identified by American Society of Clinical Oncology					
2	Yankelevich, Maxim	MD	Wayne State University, Department of Pediatrics, Children's Hospital of MI	Pediatric Hematology/Oncology, BMT	Pediatrics, Pediatric hematology/oncology

Appendix Table 2. Respondent Conflict of Interest Disclosure

	1. Research support related to the topic where clinical input is being sought		2. Positions, paid or unpaid, related to the topic where clinical input is being sought		3. Reportable, more than $1,000, health care- related assets or sources of income for myself, my spouse, or my dependent children related to the topic where clinical input is being sought		4. Reportable, more than $350, gifts or travel reimbursements for myself, my spouse, or my dependent children related to the topic where clinical input is being sought	
No.	*Yes/No*	*Explanation*	*Yes/No*	*Explanation*	*Yes/No*	*Explanation*	*Yes/No*	*Explanation*
1	No		Yes	I am employed by Vanderbilt University Medical Center as a pediatric bone marrow transplant physician. I perform several of these types of transplants each year.	No		No	
2	No		No		No		No	

Individual physician respondents answered at individual level.

Responses

- With regard to use of HCT for children who have metastatic retinoblastoma:
  - Please use the 1 to 5 scale outlined below to indicate your level of confidence that there is adequate evidence demonstrating that this use will **improve health outcomes**.

No.	Low Confidence		Intermediate Confidence		High Confidence
	1	2	3	4	5
1			X		
2		X			

  - Please use the 1 to 5 scale outlined below to indicate your level of confidence that this **clinical use is in accordance with generally accepted medical practice**.

No.	Low Confidence		Intermediate Confidence		High Confidence
	1	2	3	4	5
1				X	
2		X			

- With regard to use of HCT for children who have late-stage Wilms tumor:
  - Please use the 1 to 5 scale outlined below to indicate your level of confidence that there is adequate evidence demonstrating that this use will **improve health outcomes**.

No.	Low Confidence		Intermediate Confidence		High Confidence
	1	2	3	4	5
1		X			
2	X				

  - Please use the 1 to 5 scale outlined below to indicate your level of confidence that this **clinical use is in accordance with generally accepted medical practice**.

No.	Low Confidence		Intermediate Confidence		High Confidence
	1	2	3	4	5
1		X			
2	X				

- With regard to use of HCT for children who have osteosarcoma:
  - Please use the 1 to 5 scale outlined below to indicate your level of confidence that there is adequate evidence demonstrating that this use will **improve health outcomes**.

No.	Low Confidence		Intermediate Confidence		High Confidence
	1	2	3	4	5
1	X				
2	X				

  - Please use the 1 to 5 scale outlined below to indicate your level of confidence that this **clinical use is in accordance with generally accepted medical practice**.

No.	Low Confidence		Intermediate Confidence		High Confidence
	1	2	3	4	5
1	X				
2	X				

- Additional comments and/or any citations supporting your clinical input on the use of HCT for children who have metastatic retinoblastoma, late-stage Wilms tumor, or osteosarcoma.

No.	Additional Comments
1	It is important to recognize how rare some of these cancers, and particular indications are. For example, there are only 200-300 new cases of retinoblastoma diagnosed each year. The number of those that would be considered metastatic, would be significantly lower (<10%). Due to these small numbers, the chance of performing the gold standard randomized controlled clinical trial of transplant vs. chemo and/or radiation is nearly impossible. While the amount of data is limited regarding the role of autologous stem cell transplant in this setting, the small case reports and case series show a signal that outcomes may be improved with this aggressive treatment approach.

No.	Additional Comments
	Similar with Wilms tumor, modern chemotherapy regimens provide excellent long-term survival, therefore, the numbers of patients with recurrent disease are extremely small, making quality clinical trials very difficult to design. Evidence would indicate that there may be a signal that high dose chemotherapy followed by autologous stem cell transplant may provide improved survival in certain high risk groups, such as those with isolated pulmonary recurrence
2	Metastatic retinoblastoma: the current evidence is just not enough to make any good conclusions -small numbers of studies/ patients Wilms tumor: it appears that patients with favorable histology/ isolated pulmonary recurrences can achieve 50-60% survival rates with intensive second line conventional chemotherapy containing alkylating agents, etoposide, carboplatin. Wilms patients commonly have a single kidney when they relapse making high dose chemo more risky in terms of acute renal failure from high dose carboplatin. Osteosarcoma showed absolutely no evidence for any role of high dose chemotherapy

- Is there any evidence missing from the attached draft review of evidence?

No.	Yes/No	Citations of Missing Evidence
1	No	
2	Yes	Yankelevich M, Dolgopolov I, Ravshanova R, et al. Efficacy and toxicity of ifosfamide/cyclophosphamide, carboplatin, and etoposide (ICE/CCE) chemotherapy with or without GM-CSF in relapsed or refractory Wilms' tumor. A single institution study. Int J Pediatr Hematol Oncol. 2000; 6(5):331-8.This study showed high toxicity/ mortality from ABMT and good survival rates using conventional ICE/CCE chemotherapy

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Documentation for Clinical Review

Please provide the following documentation:

- Referring provider history and physical
- Bone marrow transplant consultation report and/or progress notes documenting:
  - Diagnosis (including disease staging) and prognosis
  - Synopsis of alternative treatments performed and results
  - Specific transplant type being requested
- Surgical consultation report and/or progress notes
- Results of completed transplant evaluation including:
  - Clinical history including comorbidities
  - Specific issues identified during the transplant evaluation
  - Consultation reports/letters (when applicable)
  - Correspondence from referring providers (when applicable)
  - Identification of donor for allogeneic related bone marrow/stem cell transplant (when information available)
- Medical social service/social worker and/or psychiatric (if issues are noted) evaluations including psychosocial assessment or impression of patient's ability to be an adequate candidate for transplant
- Radiology reports including:
  - Chest x-ray (CXR)
  - PET scan, CT scan and bone survey (as appropriate)
- Cardiology procedures and pulmonary function reports:
  - Electrocardiogram (EKG)
  - Echocardiogram
  - Pulmonary function tests (PFTs)
- Biopsy/Pathology reports including:
  - Bone marrow biopsy
  - Lymph node biopsy (as appropriate)
- Laboratory reports

Coding

This Policy relates only to the services or supplies described herein. Benefits may vary according to product design; therefore, contract language should be reviewed before applying the terms of the Policy.

The following codes are included below for informational purposes. Inclusion or exclusion of a code(s) does not constitute or imply member coverage or provider reimbursement policy. Policy Statements are intended to provide member coverage information and may include the use of some codes for clarity. The Policy Guidelines section may also provide additional information for how to interpret the Policy Statements and to provide coding guidance in some cases.

Type	Code	Description
CPT®	38204	Management of recipient hematopoietic progenitor cell donor search and cell acquisition
	38205	Blood-derived hematopoietic progenitor cell harvesting for transplantation, per collection; allogeneic
	38206	Blood-derived hematopoietic progenitor cell harvesting for transplantation, per collection; autologous

Type	Code	Description
	38207	Transplant preparation of hematopoietic progenitor cells; cryopreservation and storage
	38208	Transplant preparation of hematopoietic progenitor cells; thawing of previously frozen harvest, without washing, per donor
	38209	Transplant preparation of hematopoietic progenitor cells; thawing of previously frozen harvest, with washing, per donor
	38210	Transplant preparation of hematopoietic progenitor cells; specific cell depletion within harvest, T-cell depletion
	38211	Transplant preparation of hematopoietic progenitor cells; tumor cell depletion
	38212	Transplant preparation of hematopoietic progenitor cells; red blood cell removal
	38213	Transplant preparation of hematopoietic progenitor cells; platelet depletion
	38214	Transplant preparation of hematopoietic progenitor cells; plasma (volume) depletion
	38215	Transplant preparation of hematopoietic progenitor cells; cell concentration in plasma, mononuclear, or buffy coat layer
	38220	Diagnostic bone marrow; aspiration(s)
	38221	Diagnostic bone marrow; biopsy(ies)
	38222	Diagnostic bone marrow; biopsy(ies) and aspiration(s)
	38230	Bone marrow harvesting for transplantation; allogeneic
	38232	Bone marrow harvesting for transplantation; autologous
	38240	Hematopoietic progenitor cell (HPC); allogeneic transplantation per donor
	38241	Hematopoietic progenitor cell (HPC); autologous transplantation
	86812	HLA typing; A, B, or C (e.g., A10, B7, B27), single antigen
	86813	HLA typing; A, B, or C, multiple antigens
	86816	HLA typing; DR/DQ, single antigen
	86817	HLA typing; DR/DQ, multiple antigens
	86821	HLA typing; lymphocyte culture, mixed (MLC)
HCPCS	S2140	Cord blood harvesting for transplantation, allogeneic
	S2142	Cord blood-derived stem-cell transplantation, allogeneic
	S2150	Bone marrow or blood-derived stem cells (peripheral or umbilical), allogeneic or autologous, harvesting, transplantation, and related complications; including: pheresis and cell preparation/storage; marrow ablative therapy; drugs, supplies, hospitalization with outpatient follow-up; medical/surgical, diagnostic, emergency, and rehabilitative services; and the number of days of pre- and posttransplant care in the global definition

Policy History

This section provides a chronological history of the activities, updates and changes that have occurred with this Medical Policy.

Effective Date	Action
01/07/2011	BCBSA Medical Policy adoption
10/05/2012	Policy revision with position change
07/31/2015	Coding update
08/31/2015	Policy revision without position change

Effective Date	Action
07/01/2017	Policy title change from Hematopoietic Stem Cell Transplantation for Solid Tumors of Childhood Policy revision without position change
01/01/2018	Coding update
04/01/2018	Policy revision without position change
03/01/2019	Policy revision without position change
04/01/2020	Annual review. No change to policy statement. Literature review updated.
03/01/2021	Annual review. No change to policy statement. Literature review updated.
04/01/2022	Annual review. No change to policy statement. Literature review updated.
10/01/2022	Administrative update.
04/01/2023	Annual review. No change to policy statement. Literature review updated.
04/01/2024	Annual review. No change to policy statement. Literature review updated.

Definitions of Decision Determinations

Medically Necessary: Services that are Medically Necessary include only those which have been established as safe and effective, are furnished under generally accepted professional standards to treat illness, injury or medical condition, and which, as determined by Blue Shield, are: (a) consistent with Blue Shield medical policy; (b) consistent with the symptoms or diagnosis; (c) not furnished primarily for the convenience of the patient, the attending Physician or other provider; (d) furnished at the most appropriate level which can be provided safely and effectively to the patient; and (e) not more costly than an alternative service or sequence of services at least as likely to produce equivalent therapeutic or diagnostic results as to the diagnosis or treatment of the Member's illness, injury, or disease.

Investigational/Experimental: A treatment, procedure, or drug is investigational when it has not been recognized as safe and effective for use in treating the particular condition in accordance with generally accepted professional medical standards. This includes services where approval by the federal or state governmental is required prior to use, but has not yet been granted.

Split Evaluation: Blue Shield of California/Blue Shield of California Life & Health Insurance Company (Blue Shield) policy review can result in a split evaluation, where a treatment, procedure, or drug will be considered to be investigational for certain indications or conditions, but will be deemed safe and effective for other indications or conditions, and therefore potentially medically necessary in those instances.

Prior Authorization Requirements and Feedback (as applicable to your plan)

Within five days before the actual date of service, the provider must confirm with Blue Shield that the member's health plan coverage is still in effect. Blue Shield reserves the right to revoke an authorization prior to services being rendered based on cancellation of the member's eligibility. Final determination of benefits will be made after review of the claim for limitations or exclusions.

Questions regarding the applicability of this policy should be directed to the Prior Authorization Department at (800) 541-6652, or the Transplant Case Management Department at (800) 637-2066 ext. 3507708 or visit the provider portal at www.blueshieldca.com/provider.

We are interested in receiving feedback relative to developing, adopting, and reviewing criteria for medical policy. Any licensed practitioner who is contracted with Blue Shield of California or Blue Shield of California Promise Health Plan is welcome to provide comments, suggestions, or concerns. Our internal policy committees will receive and take your comments into consideration.

For utilization and medical policy feedback, please send comments to: MedPolicy@blueshieldca.com

Disclaimer: This medical policy is a guide in evaluating the medical necessity of a particular service or treatment. Blue Shield of California may consider published peer-reviewed scientific literature, national guidelines, and local standards of practice in developing its medical policy. Federal and state law, as well as contract language, including definitions and specific contract provisions/exclusions, take precedence over medical policy and must be considered first in determining covered services. Member contracts may differ in their benefits. Blue Shield reserves the right to review and update policies as appropriate.

Appendix A

POLICY STATEMENT (No changes)	
BEFORE	**AFTER**
Hematopoietic Cell Transplantation for Solid Tumors of Childhood 8.01.34 **Policy Statement:** I. Autologous hematopoietic cell transplantation may be considered **medically necessary** for **any** of the following: A. Initial treatment of high-risk neuroblastoma B. Recurrent or refractory neuroblastoma C. Initial treatment of high-risk Ewing sarcoma D. Recurrent or refractory Ewing sarcoma E. Metastatic retinoblastoma II. Tandem autologous hematopoietic cell transplantation may be considered **medically necessary** for high-risk neuroblastoma. III. Autologous hematopoietic cell transplantation is considered **investigational** for **any** of the following: A. Initial treatment of low- or intermediate-risk neuroblastoma B. Initial treatment of low- or intermediate-risk Ewing sarcoma C. Other solid tumors of childhood including, but not limited, to the following: 1. Osteosarcoma 2. Retinoblastoma without metastasis 3. Rhabdomyosarcoma 4. Wilms tumor IV. Tandem autologous hematopoietic cell transplantation is considered **investigational** for the treatment of all other types of pediatric solid tumors except high-risk neuroblastoma, as noted above. V. Allogeneic (myeloablative or nonmyeloablative) hematopoietic cell transplantation is considered **investigational** for treatment of pediatric solid tumors.	**Hematopoietic Cell Transplantation for Solid Tumors of Childhood 8.01.34** **Policy Statement:** I. Autologous hematopoietic cell transplantation may be considered **medically necessary** for **any** of the following: A. Initial treatment of high-risk neuroblastoma B. Recurrent or refractory neuroblastoma C. Initial treatment of high-risk Ewing sarcoma D. Recurrent or refractory Ewing sarcoma E. Metastatic retinoblastoma II. Tandem autologous hematopoietic cell transplantation may be considered **medically necessary** for high-risk neuroblastoma. III. Autologous hematopoietic cell transplantation is considered **investigational** for **any** of the following: A. Initial treatment of low- or intermediate-risk neuroblastoma B. Initial treatment of low- or intermediate-risk Ewing sarcoma C. Other solid tumors of childhood including, but not limited, to the following: 1. Osteosarcoma 2. Retinoblastoma without metastasis 3. Rhabdomyosarcoma 4. Wilms tumor IV. Tandem autologous hematopoietic cell transplantation is considered **investigational** for the treatment of all other types of pediatric solid tumors except high-risk neuroblastoma, as noted above. V. Allogeneic (myeloablative or nonmyeloablative) hematopoietic cell transplantation is considered **investigational** for treatment of pediatric solid tumors.

POLICY STATEMENT (No changes)	
BEFORE	**AFTER**
VI. Salvage allogeneic hematopoietic cell transplantation for pediatric solid tumors that relapse after autologous transplant or fail to respond is considered **investigational**.	VI. Salvage allogeneic hematopoietic cell transplantation for pediatric solid tumors that relapse after autologous transplant or fail to respond is considered **investigational**.