表2　3つのタイプの Anthracycline の心毒性（文献2を引用）

	急性型	急性発症型慢性進行性	遅発発症型慢性進行性
発症	ATC 使用後1週間以内	ATC 治療終了後1年以内	ATC 治療終了後1年以降
危険因子への依存性	不明	あり	あり
臨床像（成人）	一過性心収縮能低下 心筋壊死（トロポニンT上昇） 不整脈	拡張型心筋症 不整脈	拡張型心筋症 不整脈
臨床像（小児）	一過性心収縮能低下 心筋壊死（トロポニンT上昇） 不整脈	拘束性心筋症 and/or 拡張型心筋症 不整脈	拘束性心筋症 and/or 拡張型心筋症 不整脈
経過	ATC 中止により可逆的	進行性	進行性

ATC：Anthracycline

かに，Daunorubicin（DNR），THP-Adriamycin；Pirarubin（THP），Idarubicin（IDA），Mitoxantrone（MIT），Epirubicin（EPI），Aclarubicin（ACR）などが汎用されている。THP-Adriamycin は日本で開発された薬剤で，心毒性が少ない薬剤であるといわれている。各薬剤の心毒性を比較するのは容易ではないが，総投与量を知る上ではおおよその目安が必要である。現在われわれは，DOX を1とした場合，DNR＝0.87，THP＝0.6，IDA＝5，MIT＝4，EPI＝0.67，ACR＝0.27として換算している。

1．慢性心毒性と心不全

ATC の蓄積量が増加してくると心機能は徐々に低下し，最終的には拡張型の心筋症の状態となる。つまり心筋細胞の死滅と損傷がすすむと，進行性に左室拡張，壁の菲薄化，心収縮力の低下が起きる。心室は心拍出量の維持のために拡張し，この変化が左室壁にかかる圧力を慢性的に高める。その結果収縮力の低下がさらに進行する。拡張した心室は代謝要求量が増加してもそれに十分対応できないため，体重身長の増加や，妊娠，急性ウイルス性疾患，手術，運動などがきっかけで急性心不全を発症することがある。成長ホルモンが分泌される成長期，妊娠時の循環血液量増加を伴う体重増加や経膣分娩による動脈系の血管抵抗による圧負荷などによって心臓に通常以上の負荷が加わると心機能代償不全の危険性が高まるのである。成人期ではこのように，拡張型心筋症を呈するが小児期では，拡張型心筋症のほかに拘束型心筋症を呈することがある。心機能障害が進行すると，症状として易疲労感，運動耐用力の低下，咳嗽，呼吸困難，身体所見としては多呼吸，頻脈，肝腫大，ラ音の聴取などが認められる。しかし初期は全く自覚症状のないことが多い。また稀に急速に進行する非代償性心不全のみられることがある。

2．心毒性の誘発因子

心毒性が誘発される最大の因子は，ATC の累積投与量である。累積投与量と心毒性の関係についての研究は多い。たとえば，心不全については，DOX を430～600mg/m²投与することによって，心室の収縮能が60％低下するという報告[4]や，ATC 系抗がん剤累積投与量300mg/m²以上では，それ以下の11倍うっ血性心不全の発症率が高い[5]などの報告がある。また潜在性の心機能障害は，ATC 系抗がん剤累積投与量＜400mg/m²で11％，400～599mg/m² で23％，600～799mg/m² で47％，＞800mg/m²で100％に認めるとする報告[3]などがある。

また，ATC の使用年齢との関係は低年齢での使用が心毒性の確率を高めると報告されている。性別との関係も指摘されている。心エコーによる心収縮率やエルゴメーターを使用した検討で女子に心毒性の発現が高いとの結果がでている。この理由として女子の方が体内の脂肪量が多く，ATC の代謝が遅くなるため，長時間にわたり ATC が体内に残存，心臓への影響が大きいという論議や，ATC は脂肪組織に入りにくく，体内の脂肪の割合が男子より多い女子では同じ量が投与された場合，心臓での濃度が高くなるのではないかという論議などがある。その他，経過年数が長期にわたることなどで発症頻度が増加するとの報告や ATC の使用に加え，胸部放射線照射をすると心毒性の頻度が増すとの報告もある。一時，投与速度が速いと心毒性の増加が起こりやすいとの報告がされたが，これに対しては近年否定的な意見もでている。

さらに大量シクロフォスファミドの使用も心筋の浮腫などによる左室壁の重量と厚さの増大を起こし心臓障害の原因となることがあり，それ以前に使用していた ATC が相乗効果的に心毒性として表れることがある。

3．心機能の評価法

心機能の評価として，最も用いられているのは心エコーであろう。心エコーも検査法により様々な心臓の機能が表出できる。ATC の心毒性の発症するメカニズムによって，どのような方法が適しているのか多くの検討がなされている。主な評価法について**表3**に示す。左心室収縮機能評価の指標としては，左室内径短縮率（fractional shortening：FS）（収縮期と拡張期の左心室の径の変化率）と駆出率（ejection fraction：EF）がよく使用されている。また拡張不全の指標としては，左心室拡張早期血流波と心房収縮期波の比率 E/A がよく用いられている。しかし FS や EF は早期の心機能の異常を発見することは困難であり，少しでも早期の異常を見つけるために，運動や薬剤による負荷をかけての検討なども行われている。

表3　心エコーによる心機能の評価

1．左室前負荷		
	LVEDVI	左室拡張末期容積指数
	Peak E wave	左室流入拡張早期血流速度
2．左室後負荷		
	ESS	左室収縮末期壁応力
	SVR	体血管抵抗
3．左室収縮能		
	FS	左室内径短縮率
	EF	左室駆出率
	ESS/ESVI	左室収縮末期壁応力 / 左室収縮末期容積指数
	mVcf	平均左室内周短縮速度
4．左室拡張能		
	Peak E wave	左室流入拡張早期血流速度
	Peak A wave	左室流入心房収縮期血流速度
	E/A	左室流入拡張早期血流速度 / 左室流入心房収縮期血流速度
	E/E′	僧帽弁輪部拡張期速度

心電図でも房室伝導時間の延長，心室性期外収縮，低電位，II度房室ブロック，ST 上昇・低下，T波の変化のほかに，近年 QTc 間隔の延長による評価の有用性の報告がある。さらに負荷をかけての検査，24時間のホルター心電図，加算平均心電図などでの評価も行われている。また放射線微量元素を使用した検査も行われることがある。血清学的な方法として，脳ナトリウムペプチド（BNP）や pro BNP，心房ナトリウムペプチド（ANP），トロポニンTなども心機能評価に有用であるとの報告がある。

4．予防と治療

心毒性の予防も近年いくつもの検討がある。治療時には，心毒性の少ない ATC の使用や ATC の累積投与量の削減はもちろんであるが，デクスラゾキサンという心臓保護の

薬剤も開発されている。この薬剤は心筋細胞内に入り加水分解され，ATC 治療により生じたフリーラジカルを抑える鉄のキレート剤である。

治療終了後には，重量負荷運動の制限，肥満の防止，禁煙（喫煙は将来左室の機能障害や冠動脈疾患を起こす可能性があるため）など心毒性の予防もかかせない。

心不全を呈した場合の治療は，他の原因の心不全の治療と同じようにアンギオテンシン変換酵素（Angiotensin converting enzyme：ACE）阻害薬，アンギオテンシンII受容体拮抗剤（Angiotensin II receptor blocker：ARB），ジゴキシン，β ブロッカー，利尿剤（スピロノラクトンなど）の投与であり，最終的には心臓移植ということになる。

潜在性心機能障害に対する治療は，後負荷の増大や収縮率の減少などの異常に対して ACE 阻害薬，ARB，β ブロッカーの使用で潜在性の異常が顕在性の心不全に進行することを遅らせるというものである。しかし長期の ACE 阻害薬の使用は心臓の成長因子を阻害し，心臓の成長を制限する結果，すでに左室の壁の菲薄した者に，後負荷を増大させ，さらに左室壁を薄くするとの危惧もある。

心毒性について，治療終了後どのようなフォローアップが必要かに関して，米国の COG（Children's Oncology Group）では，治療終了後5年以上では胸部照射のない場合は ATC 系抗がん剤累積投与量が300mg/m²以上では1年に1回，それ未満の投与量では2年に1回の心エコー検査を推奨している[6]。

5．放射線照射による心機能障害

放射線治療に伴う心機能障害として，心膜炎，心筋障害，冠動脈疾患，弁の機能障害，心室内伝導異常などがあげられる。これらの障害はどれも照射量が多いと発症率が高いといわれている。心膜炎は最も一般的なもので，ホジキンリンパ腫で胸部照射を受けた患者の20～40％にみられたとの報告[7]もある。弁の異常としては閉鎖不全が多い。とくに左心の弁閉鎖不全は照射を受けた患者の16～40％にも及ぶとの報告[8]がある。

III．肺における晩期合併症

小児がんの治療後の晩期合併症としての肺への影響について，Martens らは晩期合併症として肺線維症を呈する小児がん経験者が少なくないことを報告している[9]。肺の晩期合併症の原因は主に放射線照射であるが，抗がん剤の影響で起こることもある。肺に影響を及ぼすことがある抗がん剤には，ブレオマイシン，カルムスチン（BCNU），ロムスチン（CCNU），ブスルファンなどがあるが，白血病の治療にも使用するシクロフォスファミド，メソトレキサート，ビンクリスチンなどでも引き起こされることがある。小児がんの中でも白血病に限定すると肺に起こる合併症の頻度は造血幹細胞移植を除くと非常に少ないが，それゆえ，見逃されることもあり，本稿では，少し詳細に述べてみる。

1．白血病治療に使用する抗がん剤による肺の晩期合併症

小児白血病の治療，とくに急性リンパ性白血病の治療において使用頻度が高いシクロフォスファミドで，呼吸機能の異常をみたとの報告がある。縦隔照射とともにシクロフォスファマイドを使用すると肺線維症を呈することがあると言われているが，照射をしない場合でも大量にシクロフォスファミドを使用し，重篤な拘束性肺障害を伴う致死的な肺線維症を晩期発症した症例もある[10]。一般的にシクロフォスファミドによる肺の合併症には二つのパターンがあると言われている。一つは使用後1～6カ月以内に起こる肺臓炎で，通常比較的早期に咳嗽と呼吸困難で始まる。発熱や易疲労感を伴うこともある。胸部X線

写真は両側の間質陰影または網状陰影といった非特異的な異常陰影である。これらは早期に薬を中止するか副腎皮質ステロイドの投与で改善することが多い。もう一つは長期にわたり，シクロフォスファマイドの投与を受けていた場合に起こる肺の障害で，こちらは薬を中止したあとでも起こることがある。症状は徐々に始まる非湿性の咳嗽と呼吸困難である。肺の線維化を生じるが，原因不明の肺線維症にみられるばち状爪や吸気時のベルクロラ音はない。胸部X線写真は散在性の網状または網状ないし顆粒状の陰影である。両側の胸膜の肥厚がみられることもある。こちらは進行性の呼吸不全を呈することが多い[11]。比較的低容量のシクロフォスファマイドの長期投与であっても肺線維症を呈することがある。また肺の合併症の発症は，薬剤の相互作用で起きることがある。例えば，シクロフォスファマイドとドキソルビシンやビンクリスチンの併用で肺の合併症が起きたとする報告もある[12]。

メソトレキサート（MTX）などの代謝拮抗剤に対する過敏反応として，剝離型間質性肺炎や好酸球性肺炎を呈することがある。MTX による肺毒性は，通常中止後10～45日程度で回復すると言われている。

サイトシンアラビノシド（Ara-C）では，非心臓性の肺水腫を呈した症例の報告がある[13]。

多くの抗がん剤は肺への放射線照射が治療に併用されていると肺への毒性が強まると言われている。肺がん患者を対象としたものであるが，少量の DOX と放射線治療の併用を行った患者24名のうち13名で肺炎を発症したとする報告もある。

年齢と肺機能障害との検討では，治療時 8 歳以下であると肺機能の異常が出やすいとしたものがある[14]。

2．造血幹細胞移植と肺障害

造血幹細胞移植後の肺障害のほとんどは慢性 GVHD に関係していると考えられる。閉塞性細気管支炎（bronchiolitis obliterans：BO）による障害が数％から20％に起こるとの報告があり，最も頻度が高い。骨髄移植時の前処置としての化学療法とともに全身照射（Total Body Irradiation：TBI）が行われた場合，治療中に放射線肺臓炎が起こることがある。

小児の ALL 経験者における肺機能の検討で，化学療法のみでは肺機能の異常はほとんど見られないが，骨髄移植を受けた症例では，肺機能の障害が認められ，とくに一酸化炭素肺拡散能は50％以上で低下がみられたとする報告もある[15]。

肺の感染症は移植後早期には重要な問題であるが，移植後 4 カ月以上経過してからも免疫系は安定していないため，注意が必要である。さらに慢性 GVHD のために副腎皮質ステロイドを長期間にわたり使用していると感染を助長することにもなるのでさらなる注意が喚起される。

おわりに

小児白血病の予後は大変向上したといえ，今まで述べてきたような晩期合併症を持ち，QOL のよくない小児白血病経験者が少なくないことがわかってきた。小児白血病経験者をいつまでフォローアップしていくかということは重要な問題である。近年までわが国では，白血病を含む小児がん経験者のフォローアップシステムが，一部の施設以外ではほとんど整備されておらず，晩期合併症の症状が出現して始めて再受診をするということが，一般的でさえあった。最近になり，長期フォローアップシステムの整備が重要であるということが少しずつ医療者間で認識されはじめ，現在どのような形態でそのようなシステムを構築していったらよいかが全国レベルで

検討され始めている。

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EDUCATIONAL REPORT

Long-term results of Tokyo Children's Cancer Study Group trials for childhood acute lymphoblastic leukemia, 1984–1999

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We report the long-term results of Tokyo Children's Cancer Study Group's studies L84-11, L89-12, L92-13, and L95-14 for 1846 children with acute lymphoblastic leukemia, which were conducted between 1984 and 1999. The value of event-free survival (EFS) ± s.e. was 67.2 ± 2.2% at 10 years in L84-11, which was not improved in the following two studies, and eventually improved to 75.0 ± 1.8% at 10 years in L95-14 study. The lower EFS of the L89-12 reflected a high rate of induction failure because of infection and delayed remission in very high-risk patients. The L92-13 study was characterized by short maintenance therapy; it resulted in poor EFS, particularly in the standard-risk (SR) group and boys. Females did significantly better than males in EFS in the early three studies. The gender difference was not significant in overall survival, partly because >60% of the males survived after the testicular relapse. Randomized studies in the former three protocols revealed that intermediate- or high-dose methotrexate therapy significantly reduced the testicular relapse rate. In the L95-14 study, gender difference disappeared in EFS. Contrary to the results of larger-scale studies, the randomized control study in the L95-14 reconfirmed with updated data that dexamethasone 8 mg/m² had no advantage over prednisolone 60 mg/m² in the SR and intermediate-risk groups. Prophylactic cranial irradiation was assigned to 100, 80, 44, and 44% of the patients in the studies, respectively. Isolated central nervous system relapse rates decreased to <2% in the last two trials. Secondary brain tumors developed in 12 patients at 8–22 years after cranial irradiation. Improvement of the remission induction rates and the complete omission of irradiation are currently main objectives in our studies.
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Introduction

We present here the long-term results of four studies for childhood acute lymphoblastic leukemia (ALL) of Tokyo Children's Cancer Study Group (TCCSG) conducted between 1984 and 1999.

Treatment protocol for SR and IR of the L84-11 study[1,2] was based on the early St Jude's total therapy.[3] ALL-BFM 81[4] protocol was modified and introduced to extremely high-risk group regimen for the first time. The protocols of the following three studies L89-12,[1,5] L92-13,[1,6] and L95-14,[7] were designed on the basis of the ALL-BFM framework. All the four protocols contained trials to reduce the number of patients who received irradiation, as had been reported in other studies.[8,9] The second point of analysis was on a gender difference[10–12] with respect to long-term event-free survival (EFS) and overall survival (OS). Randomized studies were mostly designed to test whether or not intermediate-dose methotrexate (ID-MTX) and high-dose methotrexate (HD-MTX) could replace the cranial irradiation. It is needed to describe the further long-term outcome of the patients who were treated in L92-13 study, which was characterized by very short maintenance therapy. We published the discordant results on the randomized comparison between dexamethasone and prednisolone in 2005, which was updated in this analysis.[7]

Materials and methods

Total of 1846 newly diagnosed patients with ALL aged 1–15 years entered into the four studies—that is L84-11 ($n=484$),

Table 1 Event-free survival, overall survival, and CNS relapse of TCCSG studies L84-11, L89-12, L92-13, and L95-14

Study	Year	Number of patients	Complete remission rate (corrected)[a]	Event-free survival ± s.e.%			Overall survival ± s.e.%			Isolated and any CNS relapse rate ± s.e.%
				5 years	10 years	15 years	5 years	10 years	15 year	10 year
L84-11	1984–1989	484	97.3 (98.6)%	71.2 ± 2.1	67.2 ± 2.2	66.3 ± 2.2	80.7 ± 1.8	74.3 ± 2.0	73.5 ± 2.1	4.1 ± 1.0 5.5 ± 1.1
L89-12	1989–1992	418	92.8 (95.7)%	67.2 ± 2.4	64.4 ± 2.4	62.3 ± 2.6	77.7 (2.1)	73.5 ± 2.2	71.9 ± 2.2	3.7 ± 1.1 5.4 ± 1.3
L92-13	1992–1995	347	96.5 (97.7)%	63.7 ± 2.7	60.1 ± 2.7	57.7 ± 2.9	80.4 (2.1)	77.9 ± 2.2	77.4 ± 2.4	1.0 ± 0.6 2.6 ± 1.0
L95-14	1995–1999	597	95.0 (97.4)%	76.8 ± 1.8	75.0 ± 1.8	—	84.9 (1.5)	82.0 ± 1.6	—	1.7 ± 0.6 2.8 ± 0.7

Abbreviations: CNS, central nervous system; s.e., standard error; TCCSG, Tokyo Children's Cancer Study Group.
[a]Corrected remission (rate %): patients who achieved delayed remission were included in remission, and censored patients during the induction phase were excluded from the total.

L89-12 ($n=418$), L92-13 ($n=347$), and L95-14 ($N=597$)—as shown in Table 1. Diagnoses were made based on morphology, immunophenotype, and cytogenetics in each institution; the ALL committee evaluated these results for eligibility. Patients aged 1–6 years presented with a leukocyte count $<20\times10^9$/l and B-precursor phenotype were classified into the standard-risk (SR) group in all the studies. Definitions of the intermediate-risk (IR) and high-risk (HR) or extremely high-risk groups varied across the four studies. Nonetheless, HR patients were mostly defined as having one of the following: initial leukocyte count $\geqslant100\times10^9$/l, age of $\geqslant10$ years, leukocyte count $\geqslant50\times10^9$/l; Philadelphia chromosome (Ph) or BCR–ABL fusion gene product positive, 11q23 chromosome translocation or MLL gene rearrangements, and T-ALL with otherwise IR-risk factors. The reminder of the SR and HR patients was assigned to the IR group. Analysis of the outcome was based on the risk classification of the NCI/Rome criteria.[13]

Leukemic-cell karyotype was obtained from 20 to 30% of the patients in the first three studies. The DNA index was measured by flow cytometry.

Infants were excluded from these studies, and their treatment results were already published elsewhere.[14–16]

Treatment

The precise regimens of L84-11,[2] L89-12,[5] L92-13,[6] and L95-14[7] studies were available in earlier publications. Table 2 provides a summary of regimens in each study.

L84-11 study (1984–1989). Both the SR and HR groups were randomized at early intensification into two arms—that is S1 and S2, and H1 and H2, respectively. In the S2 and H2 arms, the patients received three courses of ID-MTX (500 mg/m^2) with a single dose of leucovorin rescue (12 mg/m^2) at 48 h, in conjunction with double-drug intrathecal injections (DIT) before cranial irradiation. In the S1and H1 arms, 18 Gy of cranial irradiation with five doses of triple-drug intrathecal injections (TIT) were administered without ID-MTX.

The DIT consisted of methotrexate (MTX) 15 mg/m^2 $\leqslant$15 mg and hydrocortisone 30 mg/m^2 $\leqslant$30 mg, respectively. The TIT consisted of DIT and cytosine arabinoside (CA) 30 mg/m^2 $\leqslant$30 mg.

L89-12 study (1989–1992). The regimen was based on the BFM backbone in all three risk groups. There was a week of prophase treatment with prednisolone alone to evaluate initial steroid response, as BFM group described.[17] The main objective was to determine whether cranial irradiation was essential to the treatment of SR patients or not. To do so, the SR patients were randomly assigned to the SR0 and SR18 arms, and patients in the SR0 arm were given three courses of HD-MTX (3 g/m^2) with three DIT without cranial irradiation. The doses of intrathecal injection were reduced from those of the earlier study, changing to age-adjusted calculation. The patients assigned to the SR18 arm received 18 Gy of cranial irradiation and three doses of TIT. The randomization ratio in SR arms changed from 1:1 to 2:1 in the last half period, so that there were 83 patients enrolled in SR0 arm and 64 in SR18 arm. The HR group was treated with a single arm of BFM-style therapy for 2 years, modified with an insertion of HD-MTX (3 g/m^2, two courses) between the induction (Ia) and early intensification and cranial irradiation (Ib). Four courses of multiple-drug intensifications were given during the first year followed by 1-year maintenance therapy.

L92-13 study (1992–1994). A major objective was to evaluate 1-year therapy in all risk groups. The length of the maintenance therapy was kept to a minimum of 6 months in the SR group and 3 months in each of the IR and HR groups. All three risk regimens had BFM-type structures. This protocol was characterized by the use of intermediate-dose cytosine arabinoside (ID-CA, 500 mg/m^2/day for 4 days) and high-dose cytosine arabinoside (HD-CA, 1 or 2 g/m^2/day for 4 days) in the early intensification and in the re-intensification phases.

The SR regimen had two courses of HD-MTX (3 g/m^2) and two DITs. The early intensification phases were complete before week 28; 24 weeks were left for the continuous therapy. IR group was randomized either to IR18 arm with 18-Gy cranial irradiation, or to IR0 arm with two courses of HD-MTX (3 g/m^2/day) without cranial irradiation. All patients of the HR group were given 2 weekly courses of HD-CA (2 g/m^2, six doses for 3 days) and mitoxantrone (2 days) after remission induction.

L95-14 study (1994–1999). SR and IR groups were randomized into prednisolone arm (PSL) and dexamethasone arm (DEX) not only in the induction, but also in re-induction phase and three courses of late intensification for SR and two courses for IR. During remission induction, prednisolone (60 mg/m^2) or dexamethasone (8 mg/m^2) was given for 4 weeks and tapered. In the re-induction and intensification courses, prednisolone (40 mg/m^2) or dexamethasone (6 mg/m^2) were given for 2 weeks in each arm. For patients presenting with leukocyte count $\geqslant150\times10^9$/l and aged 7 years or older (assigned to allo-stem-cell transplantation (SCT) group), allogeneic bone marrow transplantation from HLA-matched family donor, if any, and autologous blood or marrow SCT or chemotherapy could be elected. For patients presented with

Table 2 Treatment protocols of the four studies

Studies	TCCSG risk	Number	Therapy period (years)	Cranial irradiation**		Remission induction	Early intensification	CNS prophylaxis	Reindution	Intensification	Continuation
L84-11	SR	194	3.5	100%	100%	P V5 Asp	**Randomized S1:CRX18/ itMHC(5) vs S2:IDMTX(3)/ itMH(3)**	**S1:none vs S2:CRX18/itMHC(5)**	Dex V2/itMH..q16m(7) Dex V2 IDMTX/itMH..q12w(4)— 2.5–3.5 years		MTX+6mp (throughout)
	HR	244	3.5		100%	P V5 Asp Cy	**Randomized H1:CRX24/ itMHC(5) vs H2:IDMTX(3)/ itMH(3)**	**H1:none vs H2:CRX24/itMHC(5)**	Dex V2 D2, Dex V2 Cy, Dex B Acr, Dex V2 Asp, Dex V2 MTX(iv)— first, second year Cy(4), HDCA(4), IDMTX/itMHC(4)—third year		MTX+6mp (throughout)
	HEX	48	2.5		100%	P V4 Asp D3 Cy1 itMHC(3)	Cy1 CA(4x4) 6mp	CRX24/itMHC(5)	Dex V4 Ad4 Asp, Cy B(8) itMH(2)	itMHC(8), PV2(4)	MTX+6mp
L89-12	SR	142	2	80%	44%	P V4 Asp T2 itMHC(1)	Vp CA(4x3) 6mp itMHC(3)	**Randomized HDMTX/ itMH(3) vs CRX18/itMHC(3)**	Dex V3 Asp T(3)	Vp4 B4 6mp/itMH(2)	MTX+6mp (1.5 years)
	IR	100	2		100%	P V4 Asp T3 itMHC(1)	CRX18 itMH(3)	Cy1 CA(4x4) 6mp itMHC(3)	Dex V3 Asp T4	P Vp4 B4 Acr(2), P Vp4 Cy4 Aap(2)	MTX+6mp (1 year)
	HR	146	2		100%	P V4 Asp T3 itMHC(1-2)	HDMTX(2)/itMH(2)	CRX18 /itMHC(3) Cy2 CA(4x4) 6mp	Dex V3 Asp T4	mP HDCA Asp Mit(2), P Vp4 B4 Acr(2), P Vp4 Cy4 Asp(2)	MTX+6mp (1 year)
L92-13	SR	124	1	44%	0%	P V4 Asp T2 itMH(1)	Mit CA(4x4) 6mp	HDMTX/itMH(2)	P V3 Asp T2	IDCA0.5gx4/Mit(2)	MTX+6mp (6 months)
	IR	122	1		47%	P V4 Asp T3 itMH(1)	Cy1 CA(4x4) 6mp itMHC(3)	**Randomized HDMTX(2)/ itMH(2) vs CRX18/itMH (3)**	P V3 Asp T2	HDCA1gx4/Mit(2) it(MH), Vp B Asp(2)	MTX+6mp (3–4 months)
	HR	101	1		100%	P V4 Asp T3 itMHC(2-3)	HDCA2gx6/Mit (2) itMH(2)	CRX18/itMHC(3) Cy1 CA(4x4) 6mp	P V3 Asp T(2)	HDCA2gx4/Mit/ it(MH)(2), Vp B Asp(2)	MTX(iv)q4W+ 6mp (3–4 months)
L95-14	SR	231	2	44%	0%	**Randomized* P vs Dex** and V5 Asp T2 itMH(2)	Cy1 CA(5x3) 6mp itMHC(3)	HDMTX/itMH(3)	**P vs Dex*** V3 Asp T3	Cy1 CA(2x5) 6mp(1), **P vs Dex*** V3 Asp(3) IDMTX(no CF)/itMH(3)	MTX(iv)+6mp, MTX+6mp (1 year+)
	IR	129	2		18%	**Randomized* P vs Dex** and V5 Asp T2 Cy1 itMH(2)	Cy1 CA(5x3) 6mp itMHC(3)	**Randomized HDMTX/itMH(3) vs CRX18/itMH(3)** Asp MTX+6mp	**P vs Dex*** V3 Asp T3	Cy1CA(2x5) 6mp(1), **P vs Dex*** V3 Asp T3(2) HDCA/Asp(1), IDMTX(no CF)(2), Cy1 CA(2x5) 6mp(1)	MTX(iv)q2W+ 6mp, MTX+6mp (1 year+)
	HR	237	2		100%	P V5 Asp D4 Cy2/ itMH(2-3)	HDCA2gx4/Asp(2)/itMH(2)	CRX18/itMHC(3) Cy1 CA(5x3) 6mp(1)	Dex V4 Ad4 Asp(1), P V3 Asp Ad2(2)	HDCA2gx8/itMH(2) IDMTX(no CF)(2), Cy1 CA(2x5) 6mp(1)	MTX+6mp (1 year)

Abbreviations: CNS, central nervous system; HEX, extremely high risk; HR, high risk; IR, intermediate risk; SR, standard risk; TCCSG, Tokyo Children's Cancer Study Group.
Acr, aclarubicin; Ad, doxorubicin; Asp, L-asparaginase; B, behenoyl cytosine arabinoside; CA, cytosine arabinoside; CRX18, cranial irradiation 18 Gy; Cy, cytoxan; D, daunorubicin; Dex, dexamethasone (8 mg/m^2 in induction 6 mg/m^2 consolidation of dex arm); HDCA, high-dose cytosine arabinoside (1–2 g/m^2); HDMTX, high-dose methotrexate (3 g/m^2); IDCA, intermediate-dose cytosine arabinoside (500 mg/m^2); itMH, double intrathecal injection of methotrexate and hydrocortisone; itMHC, triple intrathecal injection of methotrexate, cytosine arabinoside, and hydrocortisone; IDMTX, intermediate-dose methotrexate (500 mg/m^2); Mit, mitoxantrone; mP, methy-prednisolone; MTX, oral methotrexate; MTX(iv), intravenous MTX (75 mg/m^2); (noCF), no leucovorine rescue; P, prednisolone (*60 mg/m^2 in induction 40 mg/m^2 consolidation of P arm); T, THP-adriamycin (pirarubicin); V, vincristine; Vp, etoposide; 6mp, oral 6 mercapropurine.
Number after drug-dose, (Numer), repeat. Randomizations were written with bold letters. Randomized*, initially randomized for whole course. **Proportion of the patients who were initially assigned to cranial irradiation arm; actual proportion was lower than the assigned.

leukocyte count $\geqslant 100 \times 10^9$/l, or 10 years old or older with leukocyte count $\geqslant 50 \times 10^9$/l (assigned to auto-SCT group), autologous blood or marrow SCT or chemotherapy could be elected. Each institute declared the choice in advance of the study initiation.

Statistical analysis

The duration of EFS was defined as the time from the initiation of therapy to the date of failure (that is any relapse, death, or diagnosis of secondary malignancy) or to the date when patients were confirmed to be in remission and alive. Patients who did not achieve complete remission at the end of the initial induction phase or who died before the confirmation of remission were considered to have failed at day 0, even if they entered remission later with a second course or through additional treatment. The probability of EFS and s.e. was estimated by the Kaplan–Meier method (Greenwood), and differences were tested by the log-rank test. Analysis was performed with the intent to treat. 'Any central nervous system (CNS) relapse' include both 'isolated CNS relapse' and CNS relapse combined with other sites. Probability of cumulative CNS relapse was estimated by inversed Kaplan–Meier method, which involves subtraction of Kaplan–Meier products from 100%. Only patients who had CNS relapse were failure, and all the others were censored. Cumulative probability of any secondary malignancy was calculated using the same method. Patients who received modified treatment were censored at that point in time. The patients who did not enter complete remission or had died during induction were treated as at the date of the beginning of treatment. Patients who were confirmed as remaining in first remission and alive, or who were lost of follow-up, were censored for EFS analysis; all those who were alive with or without disease were censored in OS analysis at the date of last contact.

Follow-up was updated in 2008. The proportions of patients whose data of the last 5 years were available were 144 of 357 (40.3%) in L84-11 study, 197 of 306 (64.3%) in L89-12, 220 of 266 (82.7%) in L92-13, and 449 of 489 (91.8%) in L95-14.

Results

Probability of EFS, OS, and cumulative CNS relapse rate of each study are shown in Tables 1 and 3. There was no improvement in EFS during the first three studies. The OS of L92-13 improved,

Table 3 Summary of the study results

Studies	*L84-11*	*L89-12*	*L92-13*	*L95-14*
Number of eligible patients (B+T)	484	418	347	597
Number of B/T	420/32	375/43	315/32	539/58
Average age (B/T) year	5.7/8.8	5.9/8.2	5.8/7.7	5.9/7.7
Average WBC (B/T)	20.1/108.0	31.6/137.5	38.4/146.1	30.6/167.0
Number of censored early	0	1 (0.2%)	2 (0.6%)	9 (1.5%)[a]
Death during induction	3 (0.6%)	12 (2.9%)[b]	5 (1.4%)	10 (1.7%)[c]
Failure of initial remission	11 (2.3%)[d]	17 (4.1%)[e]	5 (1.4%)	11 (1.8%)[f]
Complete remission (rate)	470 (97.1%)	388 (92.8%)	335 (96.0%)	567 (95.0%)
Corrected remission (rate)[g]	477 (98.6%)	399 (95.7%)	337 (97.7%)	573 (97.4%)
Death in first remission	19 (3.9%)	7 (1.7%)	6 (1.7%)	22 (3.7%)[h]
Number of censored in first remission	13 (2.7%)	13 (3.1%)[i]	31 (8.9%)[j]	21 (3.5%)[k]
Number of patients at event free	308 (63.6%)	256 (61.2%)	180 (55.3%)	428 (71.7%)
Number of relapse after remission	123 (26.1%)	104 (26.9%)	112 (33.4%)	92 (16.7%)
Site of relapse: total	123 (100%)	104 (100%)	112 (100%)	92 (100%)
Isolated bone marrow (BM)	72 (58.5%)	70 (67.3%)	87 (78.4%)	68 (73.9%)
Isolated CNS	17 (13.8%)	13 (12.5%)	3 (2.7%)	10 (10.9%)
Isolated testis	19 (15.4%)	6 (5.8%)	9 (78.4%)	7 (7.6%)
BM+CNS	6 (4.9%)	4 (3.8%)	3 (7.2%)	5 (5.4%)
BM+testis	7 (5.7%)	7 (6.7%)	6 (3.6%	1 (1.1%)
CNS+testis	1 (0.8%)	1 (0.9%)	0	0 (0%)
Other sites	1 (0.8%)	3 (2.9%)	3 (2.7%)	1 (1.1%)
Secondary AML/MDS	0/1	3/1	0/0	2/1
Brain tumor/Other	5/1[l]	4	2	1
Any BM	85 (69.1%)	81 (77.9%)	97 (87.4%)	74 (80.4%)
Any CNS	24 (19.5%)	18 (17.3%)	6 (5.4%)	15 (16.3%)
Any testis	27 (22.0%)	14 (13.5%)	15 (13.3%)	8 (8.7%)
Any testis/males	27 (10.3%)	14 (5.8%)	15 (8.5%)	8 (2.4%)

Abbreviations: AML, acute myeloid leukemia; CNS, central nervous system; MDS, myelodysplastic syndrome; SCT, stem-cell transplantation; WBC, white blood cells.
[a]Four patients assigned in dexamethasone arm dropped off, one in prednisolone arm, and four in HR risk group dropped off.
[b]Marrow suppression and infection.
[c]Five deaths in dexamethasone arm, two deaths in prednisolone arm, three deaths in HR risk.
[d]7/11 entered into remission in the following phase.
[e]11/17 patients entered remission in the following phase.
[f]All 11 failures in HR risk group; 3 Ph+ALL, 4 chromosomal translocations, 6/11 entered into remission in the following phase.
[g]Corrected remission (rate %): patients who achieved delayed remission were included in remission, and censored patients during the induction phase were excluded from the total.
[h]18/22 deaths in HR risk group, 5 related with transplants.
[i]7/13 patients underwent SCT in CR1.
[j]26/31 patients underwent SCT in CR1.
[k]9/21 patients underwent SCT in CR1.
[l]Olfactory neuroblastoma.

compared with these of the earlier two studies. The L95-14 study achieved internationally acceptable level of EFS and OS (log-rank $P<0.0001$). The cumulative 'any CNS relapse' rate decreased from 5.5% (any CNS) in the L84-11 study to 2.8% in the L95-14 study.

Twelve treatment-related brain tumors developed in patients who had received cranial irradiation in the four studies—that is 5, 4, 2, and 1 patient, respectively. They developed in six males and six females. No brain tumor occurred in the non-irradiated patients. The tumors developed between 8 and 22 years after cranial irradiation, seven in the 18-Gy irradiated group and five in the 24-Gy irradiated group. The probability of cumulative incidence (±s.e.) of brain tumors was 1.9±0.6% at 15 years and 2.8±0.9% at 20 years among the 1234 irradiated patients. Secondary acute myeloid leukemia (AML)/myelodysplastic syndrome (MDS) developed in eight patients—that is 0/1, 3/1, 0, and 2/1 in each study. Two of them (L89-12) were confirmed to have 11q23 chromosome abnormality. Seven of the eight patients were female, whereas brain tumors developed evenly in terms of gender. AML/MDS occurred only in the irradiated patients without exception. The probability of cumulative incidence±s.e. of AML/MDS among irradiated patients was 0.57±0.25% at 3 years and 1.1±0.4% at 10 years.

Cerebrovasucular lesions such as Moyamoya disease developed after radiation in the TCCSG studies and published elsewhere.[18] Neurocognitive evaluation study was not carried out as a group.

Protocol-specific treatment result

L84-11 study. For 484 patients enrolled, EFS±s.e. and OS±s.e. were 66.3±2.2 and 73.5±2.1% at 15 years, respectively. There were 357 long-term survivors, and their median follow-up period was 16.6 years. Among survivors, seven had serious neurological sequelae, such as paraparesis or leukoencephalopathy, which developed most probably because of cranial irradiation and concentrated use of five TITs at body-surface-adjusted dose setting. Probability of cumulative incidence of brain tumors in L84-11 was 1.2±0.7% at 15 years (Tables 3 and 4; Figure 1).

Males fared significantly worse than females in terms of EFS (Table 4; $P=0.006$), but not in terms of OS ($P=0.205$). Isolated or combined testicular relapses developed in 27 out of 261 males (10.3%) and they comprised 22% of all relapses.

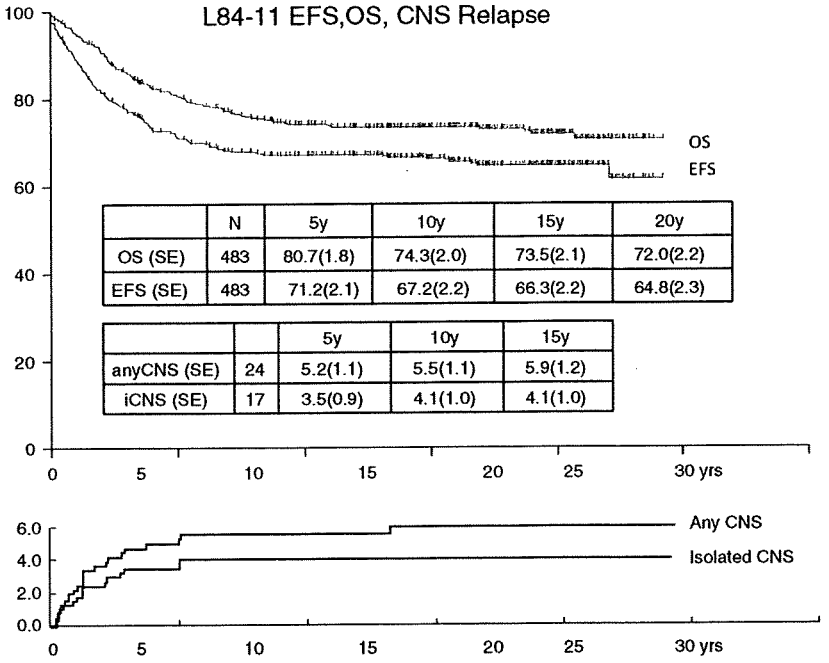
As a result of the randomized comparison in SR, the EFS±s.e. rates of the S1 and S2 arms were 68.5±4.8 and 81.0±4.1%, respectively, at 15 years (log-rank test, $P=0.071$). The probabilities of cumulative incidence ±s.e. of any testicular relapse were 24.3±6.7% in S1 arm and 4.7±3.3% in S2 arm (log-rank $P=0.015$).

L89-12 study. For the 418 patients enrolled, the EFS±s.e. and OS rate were 62.3±2.6 and 71.9±2.2% at 1 year, respectively. Probability of cumulative isolated CNS and any

Table 4 Treatment results according to presenting features in non-infant patients treated in study L84-11

Factors	*Number of patients*	*Event-free survival ± s.e.%*				*Overall survival ± s.e.%*			
		5 years	*10 years*	*15 years*	*log-rank P-value*	*5 years*	*10 years*	*15 years*	*log-rank P-value*
Non-T lineage									
NCI standard	314	72.8±2.5	69.4±2.6	68.5±2.7	0.074	83.4±2.1	77.6±2.4	77.2±2.4	0.012
NCI high	106	67.6±4.7	61.0±4.9	59.0±5.1		73.6±4.4	66.1±4.8	64.8±5.0	
T-lineage									
NCI standard	9	55.6±16.6	44.4±16.6	44.4±16.6	0.636	66.7±15.7	55.6±16.6	41.7±17.3	0.487
NCI high	23	60.9±10.1	60.9±10.1	60.9±10.1		65.2±9.9	65.2±9.9	65.2±9.9	
Sex									
Male	261	66.4±3.0	61.3±3.2	60.8±3.1	0.006	80.1±2.5	72.1±2.8	71.1±2.9	0.205
Female	222	78.1±3.0	74.5±3.0	73.1±3.1		81.5±2.6	76.9±2.9	76.4±2.9	
Age at diagnosis (years)									
1–9	392	72.6±2.3	69.2±2.4	68.5±2.4	0.068	82.7±1.9	76.5±2.2	75.9±2.2	0.007
⩾10	91	65.0±5.2	58.7±5.3	56.8±5.5		72.0±4.8	64.7±5.1	63.2±5.2	
WBC × 10^9/l									
<10k	265	76.5±2.6	73.1±2.8	71.9±2.9	0.0131	86.4±2.1	80.9±2.5	80.4±2.5	0.002
10–49k	159	64.6±3.9	59.7±4.0	5.9±4.0		75.8±3.4	67.5±3.8	66.0±3.9	
50–99k	31	63.5±8.8	56.0±9.2	56.0±9.2		70.0±8.3	58.4±9.3	58.4±9.3	
⩾100k	28	67.9±8.8	67.9±8.8	67.9±8.8		67.3±9.0	67.3±9.0	67.3±9.0	
Cell lineage									
Non-T	420	71.5±2.2	67.3±2.3	66.3±2.4	0.121	81.0±1.9	74.7±2.2	74.1±2.2	0.038
T	32	59.4±8.7	55.9±8.8	55.9±8.8		65.6±8.4	62.2±8.6	58.5±8.1	
TCCSG risk arms									
S1	102	74.4±4.4	69.9±4.7	68.5±4.8	0.071	91.0±2.9	83.1±3.8	79.6±5.1	0.227
S2	93	85.7±3.7	81.0±4.1	79.1±4.5		94.5±2.5	87.3±3.6	87.3±3.6	
H1	129	69.8±4.1	67.2±4.2	66.0±4.3	0.131	77.7±3.7	73.4±4.0	71.4±4.1	0.046
H2	113	62.7±4.6	57.5±4.8	57.5±4.8		70.9±4.3	61.9±4.7	61.9±4.7	
S1 testis	49	21.8±6.4	24.3±6.7	24.3±6.7	0.009				
S2 testis	50	2.3±2.3	4.7±3.3	4.7±3.3					

Abbreviations: NCI, National Cancer Institute risk group; s.e., standard error; TCCSG, Tokyo Children's Cancer Study Group, WBC, white blood cells. Testis: probability of cumulative any testicular relapse rate in males.



	N	5y	10y	15y	20y
OS (SE)	483	80.7(1.8)	74.3(2.0)	73.5(2.1)	72.0(2.2)
EFS (SE)	483	71.2(2.1)	67.2(2.2)	66.3(2.2)	64.8(2.3)

		5y	10y	15y
anyCNS (SE)	24	5.2(1.1)	5.5(1.1)	5.9(1.2)
iCNS (SE)	17	3.5(0.9)	4.1(1.0)	4.1(1.0)

Figure 1 EFS, OS, and cumulative incidence of isolated or any CNS relapses in L84-11 study.

CNS relapse rates were 3.7 ± 1.1 and 5.4 ± 1.3% at 15 years, respectively. Of the 306 surviving patients, the median survival period was 14.6 years. Secondary neoplasms consisted of four brain tumors, three AML, and one MDS. Remission induction rate was 92.8%, which was the lowest of the four studies (Table 3). Twelve patients (2.9%) died during or after the remission induction course, between days 10 and 82. The major cause of death was prolonged marrow suppression and infection. Of 17 patients (4.1%) failed to enter remission at the end of induction, six patients (1.4%) died within 4–24 months; one Ph positive ALL, and four with leukocyte count $>145 \times 10^9$/l. The other 11 patients entered remission in the following phase; five patients with leukocyte counts $>100 \times 10^9$/l, seven Ph positive ALL. The corrected remission rate was 95.7% when the patients who entered into delayed remission were included in remission and those who were dropped off during induction were excluded from the total number. Pirarubicin used for induction at a dosage of 30 mg/m^2 (two or three doses) was amended to 20 mg/m^2 in October 1990. Nine out of 12 deaths occurred before the amendment. Testicular relapse was significantly fewer in incidence in SR0 (HD-MTX) arm than the SR18 arm ($P=0.018$; Tables 3, 5; Figure 2).

L92-13 study. EFS ± s.e. and OS ± s.e. for 347 eligible patients enrolled were 60.1 ± 2.7 and 77.9 ± 2.2% at 10 years, respectively. Cumulative rate of isolated CNS relapse was 1.0 ± 1.0 at 10 years, which might be underestimated by high bone marrow relapse rate. The median follow-up period was 13.0 years for the 271 (78.1%) patients remaining alive, including 64 patients who experienced relapse. Twenty-one HR patients underwent hematopoietic SCT at first remission (treated as censored), and 18 were alive in CR (Tables 3, 6; Figure 3).

Brain tumors occurred in two patients. No myeloid leukemia or MDS developed. The rate of remission induction was 96.0%.

Seven of 26 relapses among 62 males in SR group relapsed very late at 5–13 years of the initial therapy, whereas females stopped recurring at 5 years. Overall, the EFS in males was 47.5 ± 4.3% at 15 years, which was significantly lower than that in females (68.0 ± 3.8%, $P=0.0003$). Males were, however, more efficiently salvaged. The OS of males was 75.8 ± 3.3% and that of females 80.3 ± 3.1% ($P=0.731$; Table 6). Ten of 14 patients with isolated or combined testicular survived. After relapse, 51 patients survived out of 84 who had undergone hematopoietic SCT (actual survival 60.7%). Of 25 who had been treated with chemotherapy, 15 survived after relapse (60%). The OS rate of 77.4 ± 2.4% eventually exceeded the preceding two studies.

L95-14 study. L95-14 study achieved 5-year EFS ± s.e 75.0 ± 1.8% and the OS ± s.e. 82.0 ± 1.6%, at 10 years' follow-up. For the 489 patients who remained alive, the median follow-up period was 10.0 years. The remission induction rate after the initial course was 95.0%. The corrected remission induction rate was 97.5% when nine patients who were off during induction were excluded and six patients who entered into remission in the following phase were included. The cumulative isolated CNS relapse rate was 1.7 ± 0.6% and 'any CNS relapse' rates was 2.8 ± 0.7% for all patients, and the latter level was 4.3 ± 1.4% in the HR. One brain tumor occurred at 8.3 years, two AML, and one MDS all were diagnosed between 1.5 and 5.2 years of therapy (Tables 3, 7; Figures 4).

The results of randomized control study was updated and showed again no advantage of DEX arm over PSL arm in SR and IR groups[9] (Tables 2, 7). Three extramedullary relapses occurred in the DEX arm, whereas eight developed in the PSL arm.

Hematopoietic SCTs, either allogeneic or autologous blood and marrow source, were elected by institutional intention to

Table 5 Treatment results according to presenting features in non-infant patients treated in study L89-12

Factors	*Number of patients*	*Event-free survival ± s.e.%*				*Overall survival ± s.e.%*			
		5 years	*10 years*	*15 years*	*log-rank P-value*	*5 years*	*10 years*	*15 years*	*log-rank P-value*
Non-T lineage									
NCI standard	314	72.8 ± 2.5	69.4 ± 2.6	68.5 ± 2.7	0.074	83.4 ± 2.1	77.6 ± 2.4	77.2 ± 2.4	0.012
NCI high	106	67.6 ± 4.7	61.0 ± 4.9	59.0 ± 5.1		73.6 ± 4.4	66.1 ± 4.8	64.8 ± 5.0	
T-lineage									
NCI standard	11	70.1 ± 14.7	70.1 ± 14.7	70.1 ± 14.7	0.169	70.1 ± 14.7	70.1 ± 14.7	70.1 ± 14.7	0.369
NCI high	32	51.9 ± 9.0	51.9 ± 9.0	43.3 ± 10.9		55.3 ± 8.9	55.3 ± 8.9	55.3 ± 8.9	
Sex									
Male	240	62.1 ± 3.2	59.8 ± 3.3	57.8 ± 3.4	0.044	76.3 ± 2.8	72.2 ± 3.5	71.1 ± 3.0	0.564
Female	178	74.1 ± 3.4	70.8 ± 3.5	68.3 ± 3.7		79.6 ± 3.1	75.2 ± 3.3	73.0 ± 3.5	
Age at diagnosis (years)									
1–9	320	70.8 ± 2.6	68.0 ± 2.7	66.6 ± 2.7	0.0002	81.8 ± 2.2	78.3 ± 2.4	77.5 ± 2.4	<0.0001
⩾10	97	54.3 ± 5.3	51.6 ± 5.4	46.2 ± 5.7		64.2 ± 4.9	57.5 ± 5.1	53.0 ± 5.4	
WBC × 10^9/l									
<10k	203	75.5 ± 3.1	70.7 ± 3.4	67.8 ± 3.5	<0.0001	88.1 ± 2.3	83.5 ± 2.7	81.5 ± 3.0	<0.0001
10–49k	133	67.7 ± 4.1	66.0 ± 4.2	66.0 ± 4.2		77.5 ± 3.7	73.5 ± 3.9	72.7 ± 3.9	
50–99k	31	47.1 ± 9.1	43.5 ± 9.1	43.5 ± 9.1		61.2 ± 8.7	54.8 ± 8.9	51.4 ± 9.0	
⩾100k	50	44.4 ± 7.2	44.4 ± 7.2	40.0 ± 7.7		46.7 ± 7.2	44.6 ± 7.2	44.6 ± 7.2	
Cell lineage									
Non-T	374	68.3 ± 2.5	65.2 ± 2.6	63.3 ± 2.6	0.053	79.8 ± 2.1	75.0 ± 2.3	73.3 ± 2.4	0.009
T	43	57.1 ± 7.7	50.7 ± 9.1	50.7 ± 9.1		59.1 ± 7.7	59.1 ± 7.7	59.1 ± 7.7	
CNS status									
CNS blast +	12	42.9 ± 15.7	42.9 ± 15.7	42.9 ± 15.7	0.132	56.3 ± 14.8	46.9 ± 15.0	46.9 ± 15.0	0.033
CNS blast–	406	68.1 ± 2.4	65.0 ± 2.4	62.8 ± 2.5		78.3 ± 2.1	74.2 ± 2.2	72.6 ± 2.3	
TCCSG SR arms									
SR0	83	75.4 ± 4.9	72.7 ± 5.1	72.7 ± 5.1	0.399	90.6 ± 3.4	89.2 ± 3.6	87.7 ± 3.9	0.148
SR18	64	71.5 ± 5.7	66.5 ± 6.0	66.5 ± 6.0		85.8 ± 4.4	80.9 ± 5.0	78.1 ± 5.5	
SR0 CNS	83	5.4 ± 2.6	—	—	0.999				
SR18 CNS	64	5.2 ± 2.9	—	—					
SR0 testis	83	3.3 ± 3.3	—	—	0.018				
SR18 testis	64	19.4 ± 7.1	22.9 ± 7.6	—					

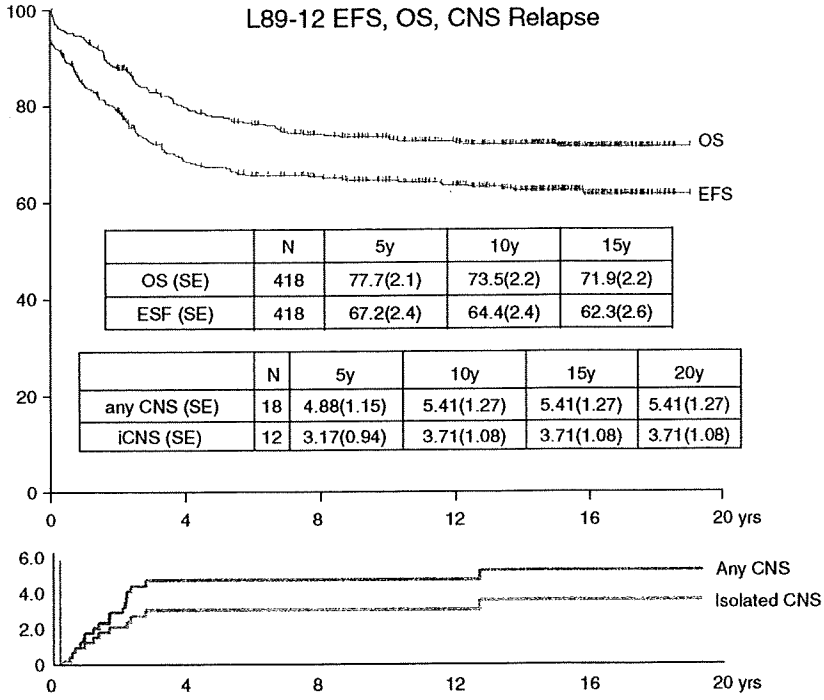
Abbreviations: CNS, central nervous system; NCI, National Cancer Institute risk group; s.e., standard error; SR, standard risk; TCCSG, Tokyo Children's Cancer Study Group; WBC, white blood cells.
CNS: probability of cumulative any CNS relapse rate.
Testis: probability of cumulative any testicular relapse rate.

treat decision in advance and executed for 61 (37 allo-SCT and 24 auto-SCT) of 126 patients who assigned to SCT (59 allo-SCT and 67 auto-SCT), among which 44 (actual rate72.1%) were alive without relapse. Of the 65 patients who assigned to SCT group, but elected chemotherapy, 30 (46, 2%) patients were alive; 29 were in first remission.

Treatment results according to presenting features

Well-documented prognostic factors were analyzed in each of the four studies (Tables 4–7). Infants were not included in these studies. Patients with B-precursor ALL and T-ALL were analyzed separately in each of the four studies, according to the NCI / Rome criteria. Age and leukocyte count at diagnosis were still independently strong prognostic factors.

Patients with T-ALL had poor prognosis. This was more evident in terms of OS (Tables 2–5). Clearly, patients with T-ALL could not be easily salvaged after relapse. Females fared significantly better than males in terms of EFS at 10 years by 13.2 points (L84-11, $P=0.006$), 11.0 points (L89-12, $P=0.044$), 15.6 points (L92-13, $P=0.003$), and –2.8 points (L95-14, males fared better, $P=0.519$), respectively (Table 3). 'Any testicular relapse' rate was 10.3, 5.8, 8.5, and 2.4% of all the males in the four studies, respectively (Table 3). The cumulative incidence of testicular relapse was significantly lower in ID-MTX or HD-MTX arms in randomized trials of the L84-11 SR, L89-12 IR, and L92-13 IR, as has been described.[19] The gender difference in EFS correlated well with the incidence of testicular relapse. Approximately 60% of the patients with any testicular relapse survived and contributed to the recovery of male OS to the same level as females. CNS involvement at presentation had negative prognostic impact on EFS (Tables 4 and 5). In L95-14 study (Table 7), patients who presented with DNA index of 1.16–1.60 showed EFS 84.2 ± 3.5%, which was significantly higher than the EFS rate of 72.3 ± 2.2% among those with DNA index < 1.16 ($P=0.005$).[20] DNA index 1.16–1.60 group of patients also fared better than those with DNA index over 1.6 (EFS of 50.0 ± 17.7%, $P=0.003$).The outcome of the patients with Ph chromosome was dismal. Hematopoietic SCT was only curative treatment strategy so far.[21]



	N	5y	10y	15y
OS (SE)	418	77.7(2.1)	73.5(2.2)	71.9(2.2)
ESF (SE)	418	67.2(2.4)	64.4(2.4)	62.3(2.6)

	N	5y	10y	15y	20y
any CNS (SE)	18	4.88(1.15)	5.41(1.27)	5.41(1.27)	5.41(1.27)
iCNS (SE)	12	3.17(0.94)	3.71(1.08)	3.71(1.08)	3.71(1.08)

Figure 2 EFS, OS, and cumulative incidence of isolated or any CNS relapses in L89-12 study.

Discussion

Nine years passed since the earlier issue was published in '*Leukemia* 2000.'[1] The 1423 survivors in the four studies are now 22.5 years old on an average, ranging from 11.6 to 39.8 years of age. Of 1233 patients who received cranial irradiation, 873 were surviving. Twelve secondary brain tumors developed very late, that is at 8–22 years after initial therapy including cranial irradiation in the four studies presented here. The development of the brain tumors seemed not to depend on the studies. Hijiya *et al.*[22] reported from the St Jude that the cumulative incidence of brain tumor except for meningioma was 3.00 ± 0.59% at 30 years. It was 2.8 ± 0.9% at 20 years in the four studies.

As for the secondary AML/MDS, the incidence was variable depending on the study. They developed only in the irradiated patients without exception. Regimens of L89-12 and L92-13 studies included etoposide, which is a topo-II inhibitor and was highly associated with the development of secondary MAL/MDS with 11q23 chromosome translocations.[23,24] Two cases were confirmed to be associated with chromosome 11q23 translocations in L89-12 study. It was noteworthy that seven out of eight secondary AML/MDS patients were female, whereas the brain tumors developed equally across genders. It was described that girls were more sensitive to anthracycline cardiac toxicity than boys.[25] In addition, cognitive impairment, short stature, and excessive weight were all more prevalent among females than males.[26] Females responded more to the chemotherapy and remained in higher EFS than that of males. All these facts may suggest that girls are more sensitive to anti-leukemic drugs, resulting in better outcome of ALL and developed more therapy-related secondary AML/MDS.

Schmiegelow recently reported from NOPHO studies that children with low thiopurine methyltransferase activity were at lower risk of relapse of ALL[27] and were at higher risk of developing secondary malignancy.[28] In the latter article, of 20 secondary malignancies, 16 AML/MDS occurred in 6 males and 10 females, although the author did not mention the gender difference.

We had not performed neurocognitive assessment as a group, but many studies showed the negative influence of the cranial irradiation on the neurocognitive function particularly for the young patients,[26] and other study described that normal neurological function was preserved when irradiation was omitted.[29]

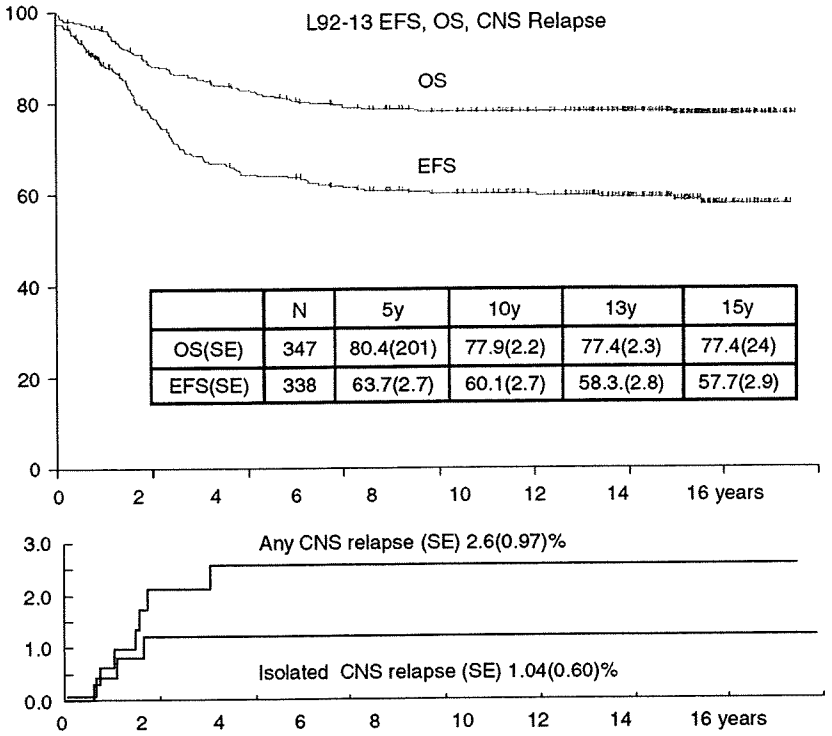
In the next study of TCCSG ALL L99-15, irradiated patients were limited to <10%. In the currently active study, T-ALL and prednisolone poor responders were irradiated. The outcomes have already been reported on the protocols with no cranial irradiation from St Jude Children's Research Hospital,[30] EORTC,[31] Nordic countries,[32] and Netherlands.[33] To eliminate the cranial irradiation, the function of intrathecal injections would be expected. The 9–11 times intrathecal injections ended before 40 weeks in TCCSG protocols even when no cranial irradiation was administered. The proper number and timing of the extended intrathecal injections for patients at risk of CNS relapse such as hyper-leukocytosis and T-ALL remained to be determined in our future studies.

Gajjar *et al.*[34] express strong caution to traumatic lumber punctures as a risk factor of CNS relapse. The L89-12 and L92-13 studies had 1-week prophase of single therapy with oral prednisolone, and the initial intrathecal injection and cerebrospinal fluid examination was given on day 8.[5,35] The prednisolone prophase without spinal puncture might well have alleviated cerebrospinal fluid infiltration before the assessment. Consequently, initial ratio of patients with CNS-2 or CNS-3 was

Table 6 Treatment results according to presenting features in non-infant patients treated in study L92-13

Factors	*Number of patients*	*Event-free survival ± s.e.%*				*Overall survival ± s.e.%*			
		5 years	*10 years*	*15 years*	*log-rank P-value*	*5 years*	*10 years*	*15 years*	*log-rank P-value*
Non-T lineage									
NCI standard	206	68.1 ± 3.3	64.0 ± 3.4	62.8 ± 3.4	0.01	88.7 ± 2.2	86.1 ± 2.4	86.1 ± 2.4	<0.0001
NCI high	108	56.5 ± 5.1	52.9 ± 5.1	52.9 ± 5.1		68.1 ± 4.5	64.9 ± 4.7	64.9 ± 4.7	
T-lineage									
NCI standard	7	83.3 ± 15.2	83.3 ± 15.2	83.3 ± 15.2	0.132	100	100	100	0.062
NCI high	25	50.8 ± 11.4	50.8 ± 11.4	50.8 ± 11.4		60.0 ± 9.8	60.0 ± 9.8	60.0 ± 9.8	
Sex									
Male	177	56.2 ± 3.9	52.4 ± 3.9	47.5 ± 4.9	0.003	80.5 ± 3.0	77.0 ± 3.0	75.8 ± 3.3	0.731
Female	170	71.3 ± 3.6	68.0 ± 3.7	68.0 ± 3.8		80.3 ± 3.0	80.3 ± 3.1	80.3 ± 3.2	
Age at diagnosis (years)									
1–9	264	66.4 ± 3.0	62.7 ± 3.1	59.7 ± 3.3	0.025	86.7 ± 2.1	84.7 ± 2.3	84.0 ± 2.4	<0.0001
⩾10	83	55.0 ± 5.8	51.7 ± 5.9	51.7 ± 5.10		67.7 ± 5.2	55.2 ± 5.3	55.2 ± 5.4	
WBC × 10^9/l									
<10k	164	65.9 ± 3.4	60.6 ± 3.9	59.9 ± 11.1	0.302	85.2 ± 2.8	82.7 ± 3.0	82.7 ± 3.1	0.008
10–49k	109	79.1 ± 4.0	64.5 ± 4.7	58.1 ± 5.4		81.5 ± 3.7	78.6 ± 4.0	77.1 ± 4.2	
50–99k	21	65.3 ± 10.6	59.9 ± 11.0	59.9 ± 11.1		76.2 ± 9.3	78.6 ± 4.0	77.1 ± 4.2	
⩾100k	50	53.9 ± 7.8	53.9 ± 7.8	53.9 ± 7.9		63.7 ± 6.8	63.7 ± 6.8	63.7 ± 6.8	
Cell lineage									
Non-T	315	64.1 ± 2.8%	60.3 ± 2.9%	57.6 ± 3.1%	0.779	81.6 ± 2.2%	78.9 ± 2.3%	78.2 ± 2.4%	0.177
T	32	58.5 ± 9.8%	58.5 ± 9.9%	58.5 ± 9.10%		68.7 ± 8.2%	68.7 ± 8.3%	68.7 ± 8.4%	
CNS status									
CNS-1	323	65.5 ± 2.8	61.7 ± 2.9	60.8 ± 2.9	0.525	80.9 ± 2.2	79.2 ± 2.4	78.5 ± 2.1	0.128
CNS-2	12	55.0 ± 15.0	55.0 ± 15.0	55.0 ± 15.0	0.076*	66.7 ± 13.6	58.3 ± 14.2	58.3 ± 14.2	
CNS-3	9	37.5 ± 17.1	37.5 ± 17.1	37.5 ± 17.1		88.9 ± 10.5	88.9 ± 10.5	88.9 ± 10.5	
DNA index or chromosome number (50–60 or others, others include cases not tested)									
1.16–1.60	25	68.0 ± 9.3	52.0 ± 10.0	52.0 ± 10.0	0.775	92.0 ± 5.4)	92.0 ± 5.4)	92.0 ± 5.4)	
Others	322	63.0 ± 2.8	60.5 ± 2.8	59.0 ± 2.9		78.5 ± 2.3)	76.9 ± 2.4)	76.3 ± 2.4)	
t(9;22) or BCR/ABL chimera message									
Present	12	16.7 ± 10.8	-	-	<0.0001	33.3 ± 13.6	33.3 ± 13.6	33.3 ± 13.6	<0.0001
Absent	335	64.6 ± 3.0	61.0 ± 2.8)	60.2 ± 2.8		82.1 ± 2.1	79.6 ± 2.2	79.0 ± 2.3	
TCCSG arms									
SR	123	65.9 ± 4.3	59.9 ± 4.5	56.3 ± 4.6		88.3 ± 2.9	84.9 ± 3.3	83.5 ± 3.5	
IR0	71	61.0 ± 5.9	58.0 ± 6.0	58.0 ± 6.0	0.942	87.1 ± 4.0	87.1 ± 4.0	87.1 ± 4.0	0.021
IR18	50	64.0 ± 6.8	60.0 ± 6.9	60.0 ± 6.9		74.0 ± 6.2	69.9 ± 6.5	69.9 ± 6.5	
IR0 testis	37	7.8 ± 5.5	7.8 ± 5.6	7.8 ± 5.7	0.053				
IR18 testis	22	26.4 ± 10.2	26.4 ± 10.3	26.4 ± 10.4					

Abbreviations: CNS, central nervous system; CSF, cerebrospinal fluid; NCI, National Cancer Institute risk group; s.e., standard error; SR, standard risk; TCCSG, Tokyo Children's Cancer Study Group; WBC, white blood cells.
IR0: the arm without cranial irradiation.
IR18: the arm with cranial irradiation.
Testis: probability of cumulative any testicular rate in males.
*CSF-1 vs CSF2 + 3.



	N	5y	10y	13y	15y
OS(SE)	347	80.4(201)	77.9(2.2)	77.4(2.3)	77.4(24)
EFS(SE)	338	63.7(2.7)	60.1(2.7)	58.3.(2.8)	57.7(2.9)

Figure 3 EFS, OS, and cumulative incidence of isolated or any CNS relapses in L92-13 study.

lower on day 8 in our studies than that on day 1 of other studies. It has been shown that the day 8 puncture did not increase CNS relapse.[5] The initial day 8 lumbar puncture is a safe method to avoid inadvertent introduction of leukemic blasts into the cerebrospinal fluid.

The duration of the maintenance therapy had been shortened step by step from 4 years in L81-10 study, 3 years for SR in L84-11 study, and 1.5 years for SR and 1 year for HR in L89-12 study without increasing relapses. The ID-MTX in S2 arm of L84-11 study efficiently reduced relapse after off therapy, whereas the control arm showed clusters of relapse starting at the point of off therapy. These results developed a hypothesis that an addition of a new intensified treatment on early phase might make it possible to shorten the duration of therapy further without sacrificing overall outcome. Randomized study could not be realized because a control arm was difficult to set. For the intensification of early therapy, ID-CA and HD-CA and mitoxantrone were administered in all risk groups. As a result, the relapse increased in both SR and HR groups. The short maintenance therapy affected more negatively on the lower-risk patients and males than on the higher risk and females (Table 6). EFS of HR patients was almost equivalent to that of SR. The early intensification might be more effective in HR than SR as CCG reported.[36] Randomized comparison of length in maintenance therapy for 18 months vs 24 months came to conclusion in ALL-BFM 81[4] and 83[37] studies, and ALL-BFM 86[38] study was amended to extend all the maintenance from 18 to 24 months. The appropriate length of maintenance therapy must be essential, particularly for the lower-risk patients and males. The duration between 18 months and 24 months were needed in the protocols of BFM-type structure. The boys had a higher risk of late relapse without sufficient maintenance therapy.

In 95-14, the randomized study in SR and IR compared between prednisolone (60 mg/m^2 at induction and 40 mg/m^2 at intensifications) and dexamethasone (8 mg/m^2 at induction and 6 mg/m^2 at intensifications) resulted in no significant difference in EFS rate.[7] Analysis with updated data on this comparison resulted in the same conclusion. Our results did not fully accord with those of other larger-scale studies. The results of CCG-1922 study[39] showed significantly better outcome in SR patients treated with dexamethasone at 6 mg/m^2 than prednisolone 40 mg/m^2. In UK Medical Research Council ALL97 trial,[40] dexamethasone given at 6.5 mg/m^2 and prednisolone given at 40 mg/m^2 were compared, and the dexamethasone arm showed better outcome. A conclusive result is anticipated in the trials with higher dose of dexamethasone at 10 mg/m^2 along with the evaluation of side effects.

In conclusion, analysis of long-term follow-up results brought us invaluable suggestions to consider for our future studies. Girls may generally be more drug sensitive than boys and they could be cured with shorter maintenance therapy than boys; at the same time, they may be at higher risk of secondary AML/MDS. The testicular relapse and lower EFS in boys were almost resolved in L95-14. TCCSG currently limited the indication of cranial irradiation to <10% of the patients. To avoid the secondary malignancy and neurological sequelae, it is of primary importance to omit the cranial irradiation and the etoposide completely as a primary therapy. Safe and effective induction and immediately given intensification, as well as appropriate length of maintenance therapy, are still major subjects to study. We seriously realized that an establishment of firm long-term follow-up system is mandatory to evaluate the ultimate result of the protocols.

Table 7 Treatment results according to presenting features in non-infant patients treated in study L95-14

Factors	*Number of patients*	*Event-free survival ± s.e.%*				*Overall survival ± s.e.%*			
		5 years	*10 years*	*13 years*	*log-rank value*	*5 years*	*10 years*	*13 years*	*log-rank P value*
Non-T lineage									
NCI standard	373	82.7 ± 2.0	81.3 ± 2.1	80.5. ± 2.2	<0.0001	92.5 ± 1.3	90.6 ± 1.5	88.9 ± 2.0	<0.0001
NCI high	183	67.4 ± 3.6	64.4 ± 3.7	64.4 ± 3.7		72.8 ± 3.3	68.5 ± 3.6	67.3 ± 3.7	
T-lineage									
NCI standard	8	87.5(11.7)	87.5(11.7)	87.5(11.7)	0.2676	100	100	100	0.095
NCI high	50	66.9 ± 6.8	66.9 ± 6.8	66.9 ± 6.8		70.0 ± 6.5	68.0 ± 6.6	68.0 ± 6.6	
Sex									
Male	340	78.5 ± 2.6	76.5 ± 2.7	76.5 ± 2.7	0.519	86.1 ± 2.1	84.4 ± 2.3	82.9 ± 2.7	0.211
Female	257	75.4 ± 2.4	73.7 ± 2.5	72.9 ± 2.6		84.0 ± 2.0	80.1 ± 2.2	78.7 ± 2.4	
Age at diagnosis (years)									
1–9	460	79.1 ± 1.9	77.6 ± 2.0	77.0 ± 2.1	0.002	88.6 ± 1.5	85.7 ± 1.7	83.8 ± 2.0	<0.0001
⩾10	134	68.6 ± 4.1	65.6 ± 4.3	65.6 ± 4.3		72.4 ± 3.9	69.2 ± 4.1	69.2 ± 4.1	
WBC × 10^9/l									
<10k	306	79.1 ± 2.3	77.2 ± 2.4	75.7 ± 2.6	<0.0001	91.1 ± 1.6	88.0 ± 1.9	86.52 ± 2.4	<0.0001
10–49k	160	74.8 ± 3.4	74.1 ± 3.4	74.1 ± 3.4		86.7 ± 2.7	85.3 ± 2.8	85.3 ± 2.8	
50–99k	58	56.9 ± 6.5	56.9 ± 6.5	56.9 ± 6.5		70.7 ± 6.0	65.8 ± 6.6	62.3 ± 7.1	
⩾100k	70	57.7 ± 6.0	55.6 ± 6.1	55.6 ± 6.1		65.4 ± 5.7	65.4 ± 5.7	65.4 ± 5.7	
Cell lineage									
Non-T	539	77.5 ± 1.8	75.5 ± 1.9	75.3 ± 2.0	0.159	86.1 ± 1.5	83.4 ± 1.7	81.4 ± 1.9	0.021
T	58	69.7 ± 6.2	69.7 ± 6.2	69.7 ± 6.2		73.9 ± 5.8	72.1 ± 5.9	72.1 ± 5.9	
CNS status									
0	378	85.6 ± 1.8	82.3 ± 2.0	81.8 ± 2.1	0.962	77.9 ± 2.0	77.9 ± 2.0	77.9 ± 2.0	0.514
1–4	183	85.1 ± 2.6	83.9 ± 2.7	80.2 ± 3		77.5 ± 3.0	74.7 ± 3.0	74.7 ± 3.0	
5–	20	90.0 ± 6.7	77.9 ± 9.9	77.9 ± 9.9		65.8 ± 11.0	65.8 ± 11.0	65.8 ± 11.0	
DNA index									
<1.16	464	74.3 ± 2.1	72.9 ± 2.1	72.3 ± 2.2	0.005*	82.5 ± 1.8	79.2 ± 2.9	78.2 ± 2.0	0.001*
1.16–1.60	124	87.5 ± 3.0	84.2 ± 3.5	84.2 ± 3.5	0.003**	94.3 ± 2.1	92.7 ± 2.4	92.7 ± 2.4	0.005**
>1.60	9	50.0 ± 17.7	50.0 ± 17.7	50.0 ± 17.7		77.8 ± 13.9	77.8 ± 13.9	77.8 ± 13.9	
t(9;22) or BCR/ABL chimera message									
Present	24	26.4 ± 9.7	26.4 ± 9.7	26.4 ± 9.7	<0.0001	41.7 ± 10.1	31.3 ± 9.9	25,9 ± 9.7	<0.0001
Absent	573	78.7 ± 1.7	76.9 ± 1.8	76.4 ± 1.9		86.8 ± 1.4	84.1 ± 15.7	83.9 ± 1.8	
t(1;19) or E2A/PBX1 chimera message									
Present	26	70.2 ± 9.5	70.2 ± 9.5	70.2 ± 9.5	0.449	73.0 ± 8.7	73.0 ± 8.7	73.0 ± 8.7	0.182
Absent	568	77.1 ± 1.8	75.1 ± 1.9	74,7 ± 1.9		85.5 ± 1.5	82.4 ± 1.6	80.8 ± 1.9	
11q23 or MLL rearrangement									
Present	5	75.0 ± 21.5	75.0 ± 21.5	75.0 ± 21.5	0.962	80.0 ± 17.9	80.0 ± 17.9	80.0 ± 17.9	0.879
Absent	589	76.8 ± 1.8	74.9 ± 1.8	74.5 ± 1.9		85.0 ± 1.5	82.0 ± 1.6	80.5 ± 1.8	
TCCSG SR+HR arm									
Dexamethasone	179	82.15 ± 2.9	80.5 ± 3.1	80.5 ± 3.1	0.5178	91.5 ± 2.1	89.1 ± 2.4	88.1 ± 2.6	0.190
Prednisolone	180	85.6 ± 2.7	83.5 ± 2.9	81.9 ± 3.2		95.0 ± 1.6	93.2 ± 1.9	90.2 ± 3.5	

Abbreviations: CNS, central nervous system; CSF, cerebrospinal fluid; NCI, National Cancer Institute risk group; s.e., standard error; SR, standard risk; TCCSG, Tokyo Children's Cancer Study Group; WBC, white blood cells.
*<1.16 vs 1.16-1.60, **1.16-1.60 vs>1.60.

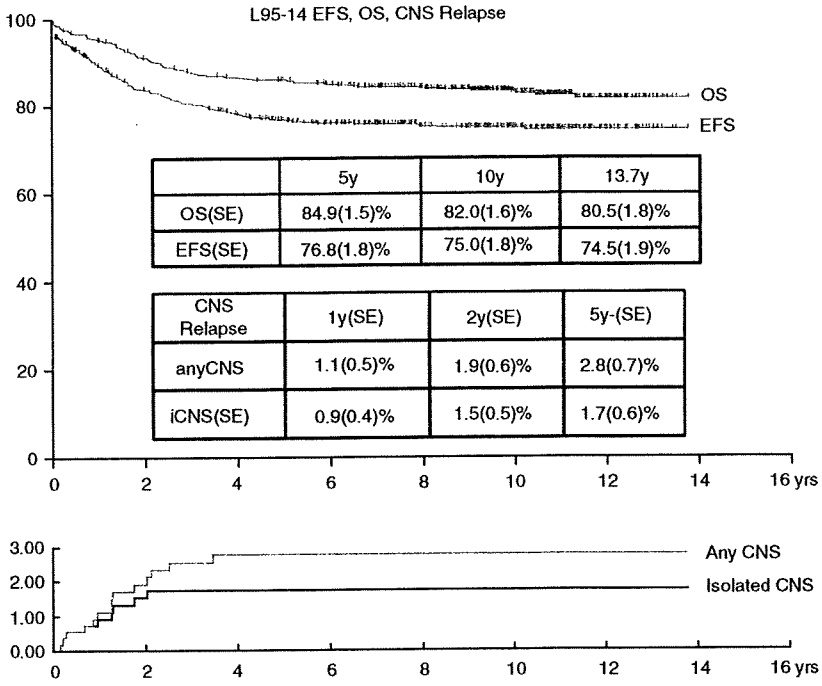


Figure 4 EFS, survival, and cumulative incidence of isolated or any CNS relapses in L95-14 study.

Conflict of interest

The authors declare no conflict of interest.

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Expression of Bone Morphogenetic Proteins in Giant Cell Tumor of Bone

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Abstract. *Background: A giant cell tumor (GCT) of bone is a locally aggressive tumor with a propensity for local recurrence. A characteristic pattern of peripheral bone formation has been described in GCT recurrence in soft tissue, and in some pulmonary metastases from benign GCT. Although the bone formation in GCT in supposedly due to bone morphogenetic proteins (BMPs), the expression pattern of BMPs in GCT has not been well investigated. Materials and Methods: The expression of BMPs in GCT tissues, cultured stromal cells from GCT, and osteoclast-like giant cells harvested by laser microdissection (LM), as well as from control osteosarcoma (NOS-1) cells was analyzed using reverse transcriptional-semiquantitative PCR. Results: BMP 2, 3, 4, 5 and 6 were expressed in the GCT tissue. The cultured GCT cells expressed BMP 2, 4, 5 and 6. The osteoclast-like giant cells expressed BMP 2, 3, 5 and 6 and BMP 5 was expressed at the highest level. Conclusion: Both stromal cells and osteoclast-like cells in GCT expressed several kinds of BMPs.*

A giant cell tumor (GCT) of bone is a distinctive locally aggressive neoplasm of undifferentiated cells. The multinucleated osteoclast-like cells apparently result from the fusion of mononuclear cells. Apart from such multinucleated giant cells, there are also two mononuclear cell types in GCT. The first has a round morphology similar to monocytes. The second cell type is spindle-shaped, fibroblast-like stromal cells (1-3). Cell culture experiments with GCT cells have revealed stromal cells to be the proliferating component of the GCT. The stromal cells probably stimulate monocyte migration in to the tumor tissue and enhance their fusion into the osteoclast-like giant cells (4-9). The giant cell itself resembles a normal osteoclast that is able to resorb bone, thus leading to extended osteolysis. Bone morphogenetic proteins (BMPs) are morphogens capable of inducing new cartilage and bone in ectopic sites. The bone forming cells (osteoblasts and osteocytes) produce BMPs (10). The proteins act as autocrine and/or paracrine factors regulating bone growth and remodeling. Recently BMP expression has also been demonstrated in osteoclasts by immunohistochemical analyses. In addition, the bone morphogenetic activity was observed in GCT tissue (11-22). Recurrence in soft tissue of GCT is a rare complication, and the tendency for these lesions to ossify is unexpected, given the lack of significant bone formation in primary or recurrent intraosseous lesions. A characteristic pattern of peripheral bone formation has been described in GCT involving soft tissue recurrence, and in some pulmonary metastases from benign GCT (1-3). This suggests that, in the extraosseous environment, the cells from GCT are able to simulate osteoblastic differentiation and bone formation. In addition, a bioassay for bone formation activity of lyophilized bone tumors has indicated that human GCT has bone morphogenetic activity, and both immunohistochemical and Western blotting studies have revealed the expression of BMP in GCT (23, 28-30). However, the expression pattern of BMPs in GCT has not yet been fully characterized.

This article describes the relationship between the expression of BMPs and the cell types in GCT.

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